# ARMED FORCES CHEMICAL JOURNAL

NOVEMBER-DECEMBER 1959

# ARMED FORCES CHEMICAL ASSOCIATION

**National Headquarters**

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**WASHINGTON 6, D.C.**

**(Federal 7-6823)**

**The members of this Association, mindful of the vital importance to national defense of chemistry, allied sciences, and the arts derived from them, have joined together as a patriotic obligation to preserve the knowledge of, and interest in, national defense problems derived from wartime experience; to extend the knowledge of, and interest in, these problems; and to promote cooperative endeavor among its members, the Armed Services, and civilian organizations in applying science to the problems confronting the military services and other defense agencies, particularly, but not exclusively in fields related to chemical warfare. (From Art. II, AFCA Constitution.)**

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The fact that an article appears in this magazine does not indicate approval of the views expressed in it by any one other than the author. It is our policy to print articles on subjects of interest in order to stimulate thought and promote discussion; this regardless of the fact that some or all of the opinions advanced may be at variance with those held by the Armed Forces Chemical Association, National Officers, and the Editors. It is the responsibility of contributors, including advertisers, to obtain security clearance, as appropriate, of matter submitted for publication. Such clearance does not necessarily indicate indorsement of the material for factual accuracy or opinion by the clearing agency.

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(This Number of THE JOURNAL is devoted exclusively to reports of the 14th Annual Meeting, except for a few items in the "With The Chemical Corps" department. The usual format will be resumed with the January-February issue—Ed.)

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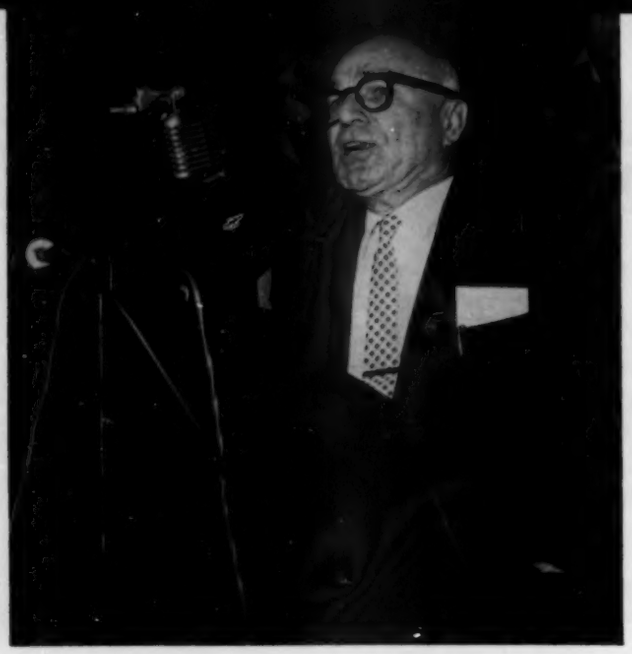


Commander S. H. Hanson, USN (left), liaison officer with A.F.C.A., and colleagues, preparing to escort group to Naval Research Laboratory.

LEFT: Brigadier General Clifford L. Sayre, USAR, President of A.F.C.A., presiding at opening session at Statler-Hilton Hotel, September 10.

# THE 14TH ANNUAL GENERAL

PRINTED IN full in this issue are the eighteen papers presented at the 14th annual meeting of the Armed Forces Chemical Association held in Washington, D.C., at the Statler-Hilton Hotel, September 10 and 11.

Seventeen of these speeches, averaging about 20 minutes each, were made at the two 9:00 A.M. to 1:00 P.M. sessions; the eighteenth was the somewhat longer banquet address.

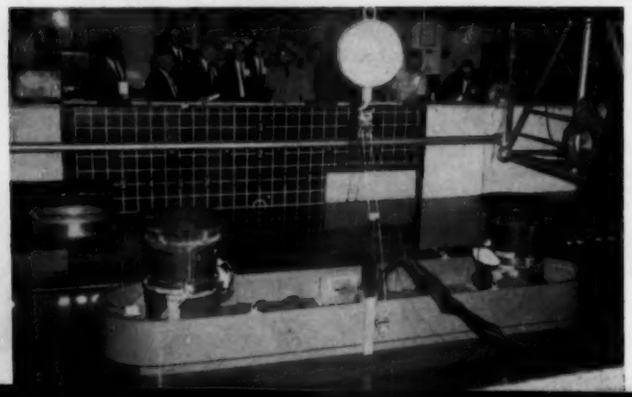
The program centered on the chemical requirements of the Armed Forces—what they look to Industry largely to provide—and accented needs for completely new or improved materials for missiles and other space-age items.

For the most part the speakers, drawn from the technical branches of their respective Services, went directly to the scientific or technological problems

TOP: Mr. George P. Sutton addressing annual banquet. BOTTOM: Sea Chanters. Navy choral group, members of U. S. Navy Band, entertained at banquet.

Mrs. Annie Sue Brown, Atlanta, Georgia, at banquet, receiving A.F.C.A. Science Teacher Award presented by Dr. Ralph E. Gibson, Chairman Awards Committee.

Testing Model of Hydro Skimmer at the David Taylor Model Basin. Blowers shown located fore and aft lift model off water surface during test.



Men at Work—A.F.C.A. Editor, John MacArthur (anither one) (foreground facing camera), preceded by Secy.-Treas. Ovid Roberts, with friends, about to board bus for Naval Laboratory visit.

RIGHT: Major General Marshall Stubbs addressing Association's Affairs Session.

# MEETING OF A.F.C.A. REPORT

underlying and explaining their stated materials requirements. References to end products, i.e., items of armament, transport or equipment, were made occasionally by way of illustration, but with few exceptions, the matter of "pay loads" and their applications in military operations did not enter into these discourses.

Many requests for copies of speeches have been received by Association Headquarters and by members of the committee in charge. This, and the belief that not only those members who unfortunately were not able to attend this meeting, but many who were there, would like to have copies of these papers for reference and careful reading, prompted a decision to publish the entire list in this one issue of THE JOURNAL.

A number of the speakers made use of lantern slides to illustrate or amplify their remarks. Only where the

TOP: A.F.C.A. group probing mysteries of the Atomic Energy Reactor at Naval Research Laboratory. BOTTOM: Mrs. Mendenhall (right), wife of Rear Admiral W. K. Mendenhall, Jr., Commandant, Potomac River Naval Command, receiving group of A.F.C.A. ladies for tea at Tingey House, Naval Weapons Center.

President's Reception—Start of receiving line (left to right facing camera), Miss Joan Mulcahy, Convention Management headquarters, Mr. Donald MacArthur, Vice President A.F.C.A. and General Chairman, Meetings Committee, and Mrs. MacArthur.

President's Reception. (Right) President and Mrs. Sayre greeting Colonel Lloyd M. Fellenz and Mr. W T. Cofer, Jr.

## INVOCATION AT BANQUET BY CHIEF OF CHAPLAINS, U. S. NAVY

REAR ADMIRAL GEORGE A. ROSSO, USN

Chaplain George Aloysius Rosso, who gave the invocation at the opening of the A.F.C.A. banquet, on September 11, was born in New York City in 1906. He was ordained at Saint Patrick's Cathedral in New York City in 1933, and in 1937 was commissioned in the Chaplains Corps of the Navy.

Chaplain Rosso had extensive service at sea during World War II. He served on the USS IOWA as Senior Chaplain from her commissioning in 1943 until April 1944. He was aboard that vessel when she carried President Roosevelt to Casablanca for the Teheran Conference with Stalin and Churchill, and was with that vessel during her subsequent service in the Pacific.

After his return to the United States in 1944 he received a Commendation from the Secretary of the Navy for exceptionally meritorious conduct in the performance of outstanding service.

Aside from his military rank, it is noteworthy that Chaplain Rosso is the second Regular Navy Chaplain who has been elevated to the rank of Monsignor in the Roman Catholic Church during his active naval service.

contents of such slides were furnished as part of the manuscripts of the speeches, are these illustrations incuded here. However, it is believed that in all cases the descriptive wording is ample to convey readily the meaning intended so that the slides are not essential.

The Navy this year was the "host" Service, and all members present will agree that its representatives carried out that role in the very best tradition. The lead-off speech was the "Welcome Aboard" from Vice Admiral Clexton, Chief of Naval Material. He sounded the keynote of the meeting with the phrase, "a stronger defense through chemistry."

### Introductory Speeches

ALL OF THE armed services participated, and the introductory speech for each service was made by an officer of general or flag rank in charge of research and development activity.

It is not practicable here adequately to outline or summarize any of these addresses. However, a few comments in respect to some of them may aid the reader in further perusal of this issue. In all cases, so it seemed, technical discussions of service needs for new materials reflected the author's careful study of his subject and his considered view that the desired properties of the materials wanted are attainable; at least considered within the realm of possibility, and are not mere figments of the imagination. Some even undertook to suggest possible lines of research approach in seeking the sort of material required.

Brigadier General Shell speaking for the Marine Corps said that while his Service, as others, has broad interests in many fields, he would confine his talk to what the individual combat Marine most needs from the chemical industry. His down-to-earth observations in that area might be summarized as "more fire power with less weight."

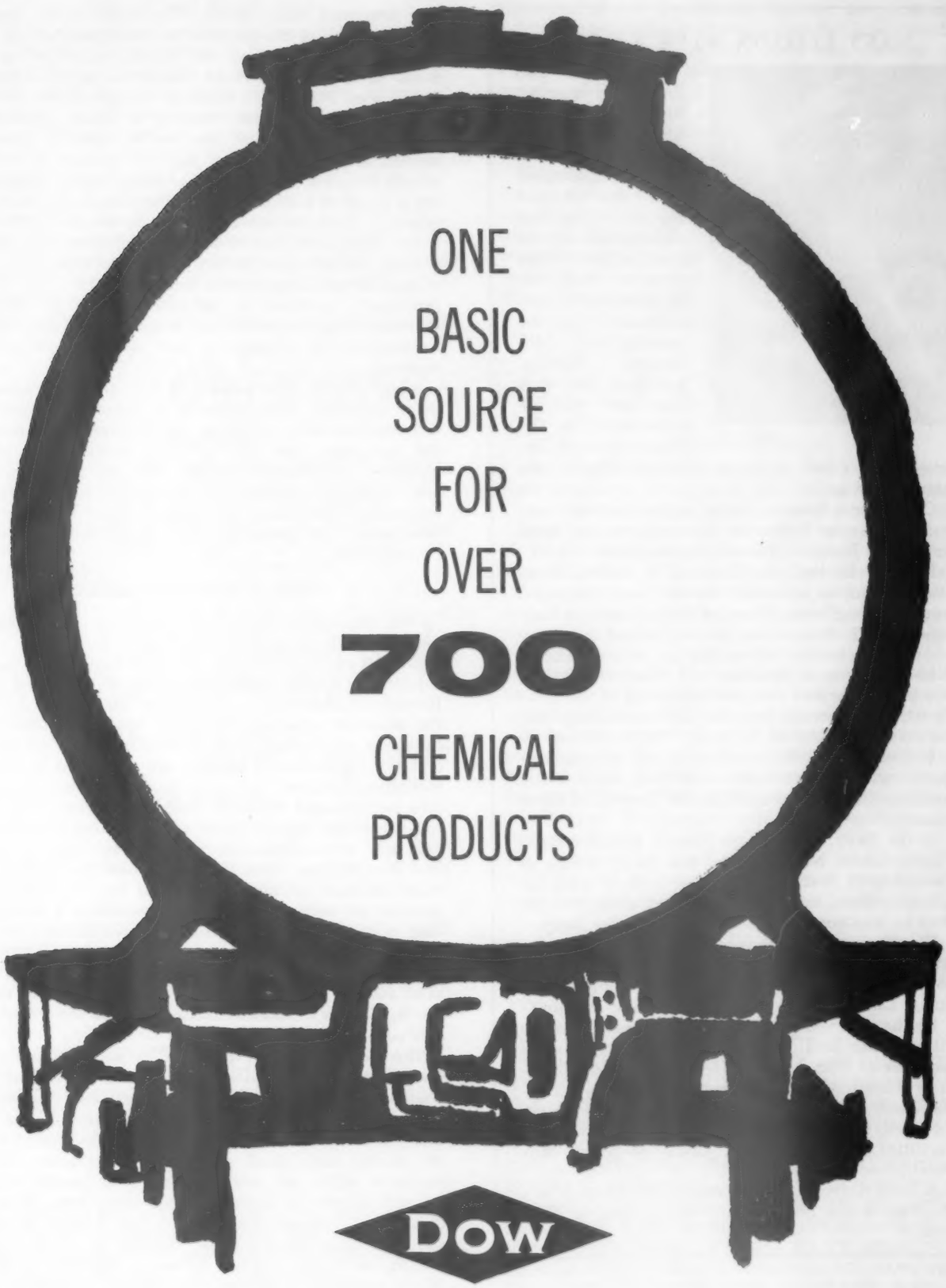
Major General Demler, Director of Research Development Hqrs., USAF, stated the Air Force needs for materials in succinct and learned fashion. One especially interesting idea he expressed was that of promoting basic research to develop a "master plan" for producing compounds with pre-determined characteristics as desired, obviating the present rather laborious process of trial and error studies of many different substances. He said the Air Force is seriously considering establishing an "Air Force Materials Center," as a focal point for all materials research activities known to the Air Force and emphasizing new applications; the information thus collected to be made available to industry.

Rear Admiral Masterson, outlining chemical requirements for the Navy, drew attention to the fact that many of the materials requirements for space vehicles are actually problems of today with the Navy in the development of the modern submarine. Storage and handling of high energy propellants in confined space, elimination of air breathing engines, need for thermoelectric generators with no moving parts, were some of the areas mentioned.

General Trudeau, in a dynamic speech that took in a wide vista of military considerations, stated the case for the Army. In the field of materials and machines he sees American preeminence today as one of technology rather than pure science, and considers it imperative that we not only maintain but increase this advantage which we now enjoy. He stressed more efficient management procedures—military, industry, labor—to provide the necessary stockpiles to insure adequate lead time for industrial mobilization and production for an emergency. He spoke of today's array of new weapons and in that connection, noting, "since the First World War there has been a great lethargy toward the use of chemical weapons," stated "much interest is now being shown in certain agents that are only temporarily incapacitating." General Trudeau went on to emphasize the seeming potential value of these non-lethal gases—including both the incapacitating type such as those to produce temporary blindness, and the behavior-pattern upsetting kind, referred to as psychochemicals.

It should be noted here that General Shell, the Marine Corps speaker, in his address also alluded to the sub-

**Brig. Gen. W. E. R. Sullivan, Deputy Chief Chemical Officer with Lt. Lee Neil of Cml. Corps, and Cmdr. Hanson, viewing Cml. Corps exhibit at Annual Meeting.**

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## NAVY LIAISON WITH A.F.C.A.

For the past two years Commander Sammy H. Hanson, USN, has been the liaison officer of the Navy Department with the Armed Forces Chemical Association. He had a major part in the planning and administrative arrangements for the Association's 14th Annual Meeting, including the very important role of coordinator for the Department of Defense with respect to the participation of all of the Armed Forces.

Commander Hanson had a varied and interesting career even before he first entered the Naval Service as Reserve officer in the summer of 1941.

Born in Springfield, Missouri, 8 May 1918, he attended public schools there and was graduated from the Southwest Missouri State Teachers College in 1937. From then until he joined the Navy he was supervisor of music in various Public School Systems in Missouri and Arkansas. During this period, he also did graduate work at the University of Arkansas in music and psychology and pursued his hobby of flying by "barnstorming" as a civilian pilot. Still another of his accomplishments was solo cornetist with the 203rd Coast Artillery Band, Missouri National Guard, for three years.

In the Navy, Commander Hanson attended Navy Flight School and received his Navy Wings in Pensacola in 1942; was assigned to duty with the Atlantic Fleet, in which he served until 1945. In 1943 he was commissioned in the Regular Navy.

His 22 years of flying experience has included duty in fighters, dive bombers, scouts, patrol bombers, seaplanes, transports, and finally in the Super Constellation used in Hurricane Hunting.

He has served as a Test Pilot; as Transport Pilot in the Berlin Air Lift; CIC Officer aboard the Carrier USS LAKE CHAMPLAIN; as Hurricane Hunter off the Florida Coast; and as a Procurement Officer for the Bureau of Aeronautics. Currently he is assigned as Assistant Head of Facilities Review Section, Office of Naval Material.

A 32nd degree Mason, Commander Hanson is a member of the Shrine Band of Alexandria, Virginia.

ject, stating the Marine Corps is following with interest the developments in the psycho-chemical field.

### The Banquet Address

MR. GEORGE P. SUTTON, Scientific Director of ARPA (Advanced Research Projects Agency), in his banquet speech entitled "Chemical Research and Advanced Military Developments," told of some of the Government's aspirations or objectives in basic space research, and presented many specific challenges to the chemical industry. One of the projects he mentioned was to step-up by 10 to 20 per cent the "specific impulse" of solid fuels. This, he said, would double the payload of such missiles as POLARIS. Another challenge was for thin metal sheet for rocket engines to withstand 5,500°F. These are but two of the many research areas he named. Mr. Sutton told of ARPA's support of new research projects at universities where teams, representing a range of sciences and engineering fields, will work together. Such across-the-board cooperative effort, he feels, offers best hope of scientific achievements. He indicated concern that industry tends to skim the cream of science and engineering talent, and to offset this he proposed a scheme of "sabbatical leave in reverse," whereby industry would lend scientists and engineers to universities for periods of part or full time duty as teachers.

Many of the ideas expressed and questions raised in these speeches here referred to were developed and discussed at more length in the intervening speeches. It did not seem that the order of presentation of the speeches—intermixed among the Services—followed any particular pattern or design. Consequently, for convenient reference, the papers given are presented here in Service groupings; Navy and Marine Corps; Air Force; Army.

### Visits to Navy Installations

THE TWO afternoons of the meetings were taken up with visits to nearby technical and scientific establishments of the Navy. On the first day, September 10, the trip by special busses was made to the noted Naval Research Laboratory, a veritable complex of facilities for scientific studies of many kinds; its numerous buildings are spread over a considerable area of land and several thousand persons are employed at this installation. Limited time and space accommodations of labs necessitated separate tours and dividing the visitors into two groups. One of these tours included a look-see at the research, development and testing of the Navy's gas mask for shipboard personnel. The mask is made of thin rubber and has a flat disc-like canister at each cheek. There was also an interesting visit to a laboratory where radioactive fall-out samples collected in the western hemisphere are received and studied and results evaluated and plotted. All groups then visited the Navy's atomic energy reactor—one of the first such installations for research constructed in this country.

The next afternoon provided a no less interesting tour of the David Taylor Model Basin, where the Navy conducts scientific studies of oceanographic and weather considerations in ship hull design and propulsion. Chief element here—though there are many others of interest—is the basin itself, a body of water some 100 feet or more wide and almost a mile in length entirely housed in a single building, itself something of an architectural and engineering wonder. The shop where the fascinating model ships, usually about 20 feet in length, are made, later to be tested against the effects of wave-making machines or other environmental contrivances in the basin, was visited; also two mathematical computing machines, one of which has a word memory of some 32,000 words.

These two "field trips" were most agreeably and hospitably conducted by Navy officers who met and joined the A.F.C.A. groups at the hotel. It is believed the Association members attending were deeply impressed and appreciated these opportunities to glimpse some of the extensive scientific foundations of the U. S. Navy.

### Business and Social Affairs

A short general business session was held at 5 P.M., September 10, on return of the members from the Naval Research Laboratory. Major General Marshall Stubbs, Chief Chemical Officer of the Army, addressed this session briefly, expressing appreciation of the role and activities of A.F.C.A. in support of National Defense.

General Sayre, presiding, called to the rostrum Mr. Glenn A. Hutt, past-president of the Association, and presented him the Association's customary gift to Annual Meeting chairmen—an engraved silver salver. This was in "belated but none the less sincere" recognition of Mr. Hutt's services in that capacity in 1955, before his election as president.

Also at this session, A.F.C.A.'s annual award to the Chemical Corps installation having the outstanding safety record of the year was presented. The award is a bronze plaque and, in this case, was received from President Sayre by Mr. C. J. Maupin, Deputy Commander of Pine Bluff Arsenal, and a Director-at-Large of A.F.C.A., on behalf of the Arsenal and Colonel Russell W. Dodds, the Arsenal Commander, who was not able to attend the meeting.

No statistics of this meeting were available at this time, however, it was subsequently learned that, pending official count, the registration, including guests, was between 250 and 300, the number being about the same as the turnout last year. Especially noteworthy was the fact that the advance listing based upon early registrations showed some 52 chemical, engineering or research

*(Continued on page 10)*

# GREETINGS TO A. F. C. A.

**—TELEGRAM—**

GREETINGS TO THE MEMBERS OF THE ARMED FORCES CHEMICAL ASSOCIATION ASSEMBLED IN THEIR FOURTEENTH ANNUAL MEETING.
IN THIS TECHNOLOGICAL AGE, CONTRIBUTIONS TO BETTER LIVING AS WELL AS NATIONAL SECURITY HAVE BEEN ADVANCED BY THE CLOSE WORKING RELATIONSHIP BETWEEN OUR MILITARY SCIENTISTS AND THOSE IN OUR GREAT INDUSTRIAL AND ACADEMIC LABORATORIES. ALL WHO LIVE IN THE COMMUNITY OF FREE NATIONS HOPE THAT THESE COOPERATIVE EFFORTS WILL BE AS PRODUCTIVE IN THE FUTURE AS IN THE PAST.
BEST WISHES FOR A FINE MEETING.

DWIGHT D EISENHOWER

**—TELEGRAM—**

GREETINGS TO ALL MEMBERS OF THE ARMED FORCES CHEMICAL ASSOCIATION ON THE OCCASION OF YOUR FOURTEENTH ANNUAL MEETING. THE NAVY AS HOST SERVICE WELCOMES YOU TO WASHINGTON.
RAPID DEVELOPMENTS IN TECHNOLOGY AND MILITARY EQUIPMENT HAVE BROUGHT THE MEMBERS OF THE MILITARY, SCIENTIFIC AND INDUSTRIAL COMMUNITIES INTO A CLOSER WORKING RELATIONSHIP THAN EVER BEFORE. THIS RELATIONSHIP IS ESSENTIAL TO OUR COUNTRY'S FUTURE, AND YOUR ORGANIZATION IS PLAYING A MAJOR PART IN INCREASING ITS EFFECTIVENESS. CONGRATULATIONS AND BEST WISHES FOR A SUCCESSFUL MEETING.

WILLIAM B. FRANKE, Secretary of The Navy

**—LETTER—**

On behalf of the United States Army, I extend my hearty congratulations and all good wishes to the members of the Armed Forces Chemical Association on the occasion of your 14th Annual Convention.
The record of AFCA over the years is an outstanding example of the teamwork between American Science and Industry and our Armed Forces which has contributed so much to keeping our Nation strong and safe. We in the Army deeply appreciate your fine cooperation.

Sincerely,
WILBER M. BRUCKER
*Secretary of the Army*

**—LETTER—**

I take great pleasure in extending heartiest congratulations and best wishes from the United States Marine Corps to you and to each and every member of the Armed Forces Chemical Association upon the occasion of the fourteenth annual meeting of your Association.
You can reflect with the deepest satisfaction upon the steady growth of your Association over the years and the many valuable contributions made by the Association to our nation's security. Your contributions to the defense effort in scientific and technological fields are as important to the chemical industry as that industry itself is to our nation's defense. Your Association's excellent publication, the *Armed Forces Chemical Journal,* and the interchange of professional ideas which your Association generates are of invaluable assistance in keeping the Marine Corps abreast of developments in the application of science to the problems confronting the Services. We Marines hold your Association in the highest esteem.
With warmest personal regards and every good wish for the continued success of the Armed Forces Chemical Association for many years to come, I remain

Sincerely yours,
R McC. PATE
*General, U. S. Marine Corps*
*Commandant of the Marine Corps*

**—TELEGRAM—**

ON BEHALF OF THE NAVY I AM PLEASED TO WELCOME TO WASHINGTON THE MEMBERS OF THE ARMED FORCES CHEMICAL ASSOCIATION ON THE OCCASION OF THEIR FOURTEENTH ANNUAL MEETING.
THE CONSTANTLY GROWING CHALLENGES TO MODERN CHEMICAL SCIENCE POSED BY THE DEFENSE EFFORTS OF THE UNITED STATES MAKE THE EXPERIENCE, KNOWLEDGE AND THE VAST RESOURCES OF YOUR MANY MEMBER ORGANIZATIONS INVALUABLE TODAY. PAST ASSOCIATIONS BETWEEN THE MILITARY AND THE AFCA HAVE ALWAYS BEEN MARKED BY EXCELLENT COOPERATION AND SOLID ACHIEVEMENT. I KNOW IT WILL CONTINUE.
CONGRATULATIONS AND BEST WISHES FOR ANOTHER HIGHLY SUCCESSFUL MEETING.

W. K. MENDENHALL, JR.,
*Rear Admiral, U. S. Navy*
*Commandant Potomac River Naval Command*

# "A STRONGER DEFENSE THROUGH CHEMISTRY"

**"Welcome Aboard" Address Opening the 14th Annual Meeting of A.F.C.A., Washington, D.C., Sept. 10-11, Stresses Importance of Association in Providing Defense-Industry Linkage.**

By VICE ADMIRAL EDWARD W. CLEXTON, USN
*Chief of Naval Material*

**General Sayre, Distinguished Members and Guests:**

WELCOME to the 14th Annual Meeting of the Armed Forces Chemical Association.

The Navy appreciates the honor of acting as your "Host Service" this year.

I bring you the greetings of the Secretary of Defense and the Secretaries and Chiefs of your Armed Services. All send you their best wishes for a successful and fruitful convention. By the looks of your Agenda they have despatched much of their top talent to insure its success.

Your Association is fulfilling a crying need today, that of providing a means of communication between Defense and Industry.

You men of Industry are here to acquire a better knowledge of the needs of the Services, to gain the intimate facts on our progress to date, and to see where your particular talents and products can be used.

We, of the Armed Services, are here to outline our requirements of the present and the future, to communicate to you our successes and failures and to see where we can use Industry to further our efforts.

We all hope that what is seen and heard individually will be applied collectively to build a stronger defense through chemistry.

I need not dwell long on the overpowering contribution that the chemical industry made to the success of the fighting in World Wars I and II. Products such as smokeless powder, TNT, mustard, Lewisite, white phosphorous, torpex, were all researched, developed and produced in the quantity required on time, although when the wars started there was no munitions industry. This teamwork of defense and industry amazed the world and contributed immeasurably to winning those wars.

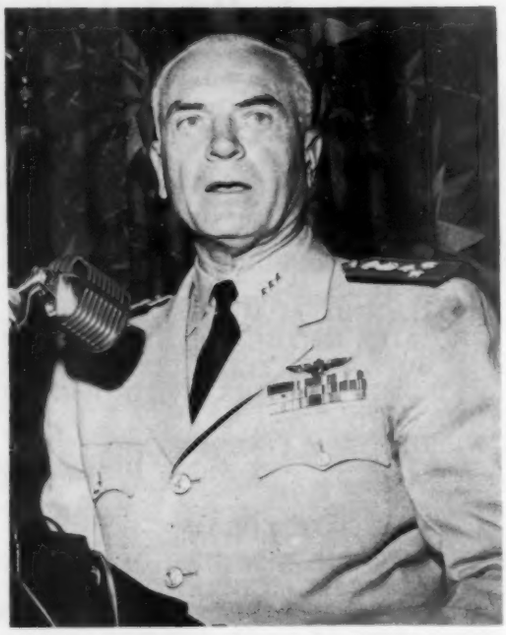
Today our Armed Forces are strong. We are planning to keep them that way. We believe the way to PEACE is through STRENGTH. We cannot match the manpower of the Communists man for man, nor will we build five hundred submarines because such a fleet cannot maintain control of the seas. Our needs for aircraft are different than theirs. Our family of missiles must meet our needs for offense and defense.

There are characteristics that we must have in all our arsenal of weapons, and they are superior performance, 100% reliability, great versatility and mobility.

Every day brings new challenges, new technological demands, new horizons. We are researching, developing, testing and evaluating to the tune of about three billion dollars a year. This stupendous effort is in the Defense Department alone. Such an effort will bring about a revolution in new discoveries, new techniques, new knowledge that will change not only our way of fighting, but our whole national life, and eventually insure our success in the field of foreign trade.

This defense effort must be augmented by your industry efforts, your talents, resources, laboratories and

*(Continued on page 10)*



Vice Admiral Clexton, born on Staten Island, New York, in August, 1900, attended public schools and Columbia University in New York City, and served as enlisted man in the U. S. Army during the World War I. In his subsequent assignment to the U. S. Naval Academy, he early won distinction as a member of both the plebe and the varsity rowing crews, the "N" Club, and Water Polo Team; served as Midshipman Lieutenant Commander; was President of the Class of 1924. He was graduated fourth in his class. Subsequently he attended the Naval Postgraduate School and, still later, Massachusetts Institute of Technology where he received a Master of Science degree. In 1933 he was designated Naval Aviator. In World War II, he served on the carriers, USS RANGER and USS YORKTOWN. He was promoted to the rank of Rear Admiral in 1953 and to Vice Admiral in 1956.

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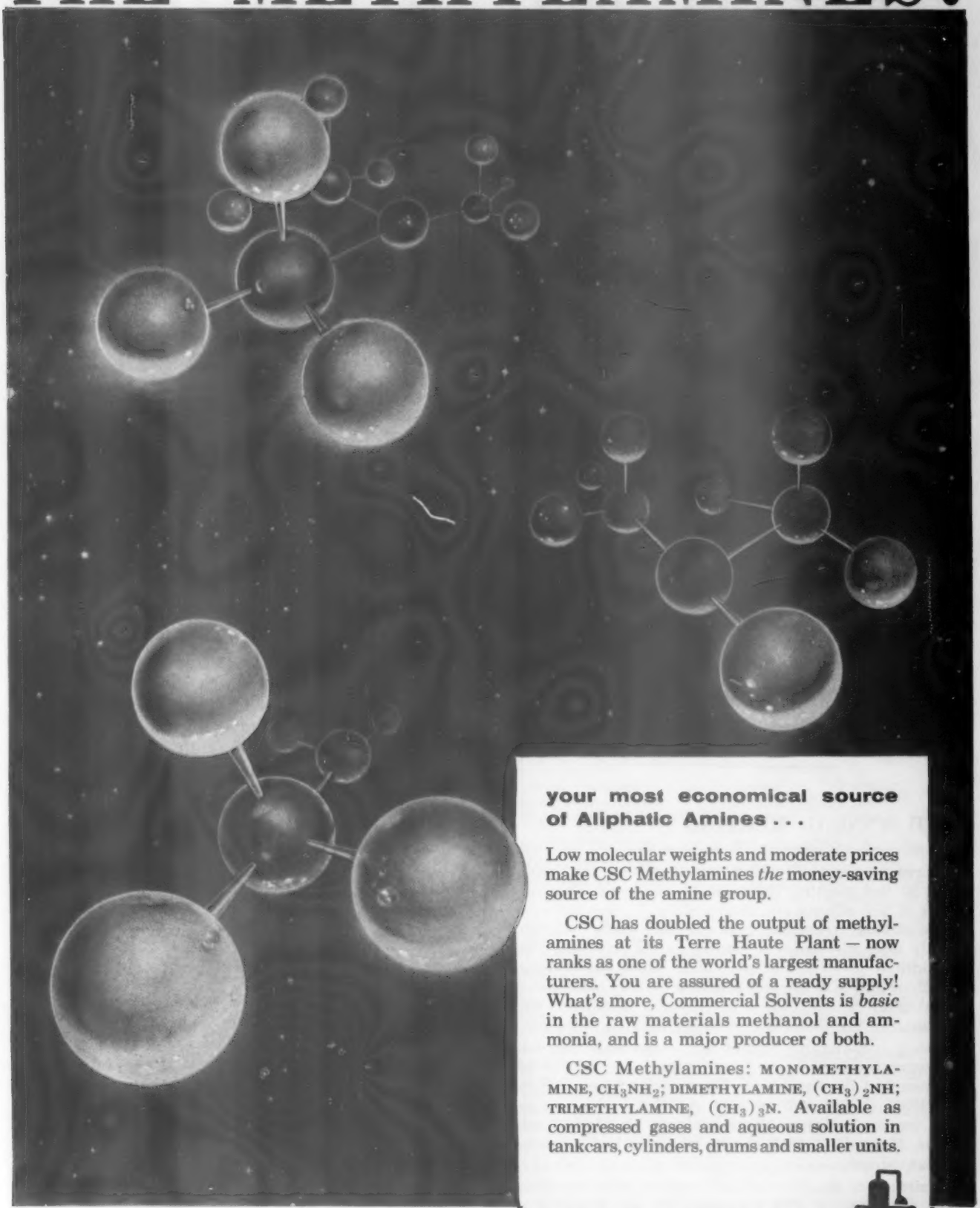

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## A STRONGER DEFENSE

*(Continued from page 8)*

research effort. This is your part in this new type of war we are in today.

Let us bring together our men of vision, our uncommon men, so that they may, by a free exchange of ideas, gain knowledge and lead us to great advances in the science of chemistry. Your convention is one means of fostering this interchange.

We, in Defense, are aware that your know-how and new discoveries are vital elements in the success of your individual businesses. We are sensitive to your interests and we propose to see that they are protected.

Do not overlook, however, the quality and quantity of knowledge being made available by the Defense research and development effort.

In your own publication of January-February 1959, Mr. William T. Read outlines many releases from the Office of Technical Services which indicate the broad scope of our defense research findings. They range from corrosion resistance coatings on molybdenum turbine blades, to making clouds for the farmer, to dissipating clouds for the aviator, to the large scale production of quartz crystals to new methods of protection of personnel and material and to a method to cut in half the cost of atomic power by extending the core life.

The Armed Forces owe a deep debt of gratitude to the Chemical Industry for the strength of our Defenses today. You are the essential big push behind all the missiles of our Armed Services. Without you none of them would exist.

We look to you to profit from this meeting, to learn something of value from the program to be presented and we eagerly look to substantive forward leaps of progress in the chemical industry.

In closing, I do wish you every success for an enjoyable and profitable meeting. Have a good time! And, don't forget—"take something" and "leave something," so that our mutual efforts will be reflected in greater strength and well being for the United States.

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## 14TH ANNUAL MEETING

*(Continued from page 7)*

concerns represented. There was a substantial enrollment at the meeting from the U. S. Army Chemical Corps of key officers and civilians.

The annual reception and cocktail party followed shortly after the business session. In the receiving line, in addition to President and Mrs. Sayre, were Vice-President and Mrs. Donald MacArthur. Mr. MacArthur, Washington representative of Koppers Company, was chairman of the General Committee on Arrangements.

A very considerable part of the liaison and coordination work involved in the framing and execution of the program had devolved upon Commander Sammy Hanson, USN., liaison officer with A.F.C.A., who was on deck for the occasion. There too was his Marine colleague, Major R. J. McNicholas, who also had rendered substantial aid.

Chairmen of Mr. MacArthur's various subcommittees were also out for this occasion. All are Washington Representatives of their respective companies, viz.,—Mr. Douglas Weiford of Stauffer Chemical Co.; Rear Admiral M. P. Hottel, USN Retired, of National Lead; Mr. Carroll W. Hayes of Celanese Corporation; Mr. Marvin Marcus of Lummus Engineering; and Dr. G. P. Vincent of Olin-Mathieson.

The registration and certain other administrative and clerical duties in connection with the planning and execution of the program were carried out by a Washington firm specializing in handling conventions, which was retained for the meeting.

Considerable attention was given to the program of this meeting by certain national publications concerned with science and technology. Articles of some length about the program were published by CHEMICAL WEEK, BUSINESS WEEK, THE OIL, PAINT AND DRUG REPORTER, and by the magazine MISSILES AND ROCKETS.

The meeting had been preceded the night before by the semi-annual fall meeting of the Board of Directors, which was held at Army and Navy Club in Washington. This meeting was particularly well-attended and brought forth discussion of various matters of current concern.

No detailed report of the proceedings was made at the later business session of the Association, as is usu-

*(Continued on page 19)*

## A MESSAGE FROM GENERAL SAYRE

October 5, 1959

To the Members and Friends of A.F.C.A.:

Our Fourteenth Annual Meeting has come and gone. From my own observation and the many comments that have been expressed, it was a most successful meeting. The technical program, so well organized by the Navy, was particularly fine and, in some measure, departed from our previous traditional format.

I trust this wider spectrum of technical subjects, as evidenced in this issue of THE JOURNAL by the verbatim reports of speeches at the meeting, will find an enthusiastic response from our members. Dr. Read's "Defense Chemistry in the News" has already pointed the way to an enlargement of interest, and since our members—individual, group, and sustaining—cover the whole industrial chemical and many allied fields, it seems fitting that the Association broaden its horizons accordingly. But write in to the Editor, or to me; let us know your views about the type of meeting programs you prefer and coverage of them in our magazine. That is the only way we can be certain that our programming is satisfactory.

In closing, I want once again to express the grateful thanks of our Association to the Navy, the Air Force, the Marine Corps, and the Army, including particularly the Chemical Corps, for their splendid cooperation; to the sponsors and contributors for their generous assistance; to the Meeting Committee for their efficient work; and, finally, to all those members and friends who came to Washington to crown it all with success.

Respectfully and sincerely,
CLIFFORD L. SAYRE, *President*

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*The Banquet Speech*

# CHEMICAL RESEARCH AND ADVANCED MILITARY DEVELOPMENTS

By

**Mr. George P. Sutton**

***Chief Scientist, Advanced Research Projects Agency***

It is indeed an honor and pleasure to address your dinner meeting here tonight. After some general observations on the subject of chemical research and advanced military development, I will discuss for you several specific examples of work which is currently being done by ARPA and which is related to various fields of chemistry and chemical engineering.

Ever since John Winthrop Jr. started to manufacture saltpeter and alum in Massachusetts in the year 1635, the chemical industry has grown in size and importance until it is today one of the largest industries of our country. Out of the 92 chemical elements that exist in nature we have learned to build synthetically over one million different chemicals which are used for many diverse purposes both civilian and military. To this new fund of knowledge we are adding new compounds at the rate of 30,000 to 40,000 per year. Indeed it is a poor day in one of the large chemical concerns if not at least one new chemical is discovered in its laboratories. We have learned how to organize atoms into patterns, how to produce molecules with twisted structures and how to use relatively simple and available raw materials to engineer molecules that are needed for specific purposes with special properties in elasticity, electrical inertness, or temperature resistance. The progress in the last 75 years has been more than phenomenal.

Ever since ammunition was made in America to support King William's war which lasted from 1689 to 1697, we have used many chemicals in military applications. Many of the new compounds find different applications in military technology. We in the Department of Defense have learned to depend on many of these compounds to find their way into military weapons systems and to help improve the performance, reliability, endurance and effectiveness of our military arsenal. We are still looking for other new chemicals that will help us improve our military system and I will not be surprised if some of these compounds will germinate new industries.

Let us consider some of the examples of the new plastics that find their way into missiles, space vehicles and other modern weapons systems. For example, we have learned to use plastics in rocket engines where their low density, their poor thermal conductivity, their relatively inert chemical nature and their high strength are very desirable. I myself have had the experience of working on a development using glass fibers in a matrix of epoxy resins for a structural shell of solid and liquid rocket thrust chambers. Because these impregnated glass fibers are lighter in weight than comparable metal parts and because they are considerably cheaper to fabricate, they have been found to be desirable in rocket engine technology. However, our rocket engine manufacturers are still looking for better plastics, with good resistance to humidity and temperature variations.

Mr. George P. Sutton, the banquet speaker, although only 38 years of age, can count 16 years experience in the rocket engine and guided missile industry. Now chief scientist of the Defense Department's space agency known as ARPA (Advanced Research Projects Agency), Mr. Sutton has Bachelor and Master of Science degrees in Mechanical Engineering from California Institute of Technology. He taught at Cal-Tech, and has a current teaching assignment at Massachusetts Institute of Technology. Author of technical articles and books on rockets and related subjects, he is a former president of The American Rocket Society and a Fellow of the British Interplanetary Society.

As you know, some of our liquid rocket propellants are extremely corrosive and chemically active. In all rocket engines there is a need for plastic materials which can be used as gaskets and seals between flanges and in rotating or moving equipment such as in valves and pumps. Certain fluorinated hydrocarbons such as teflon or Kel-F have been found to have no impact sensitivity with liquid oxygen or nitric acid and have been used satisfactorily. One of the most active liquid propellant oxidizers is elemental fluorine (B. P. + 12°C). As yet we have not found a plastic mate-

rial capable of withstanding the corrosive action of concentrated fluorine. All plastics which have been tested to date have not been proven to be completely inert to the action of fluorine under all environmental conditions. We have an urgent need for a plastic material to use for seals, gaskets and O-rings for lightweight machinery of fluorine carrying rocket engines. It is my hope that one of you gentlemen will come up with a solution.

In the electrical equipment of missiles, space vehicles and military devices good electrical insulators have been made out of many different plastics. Such things as epoxies, polyamides, polysulfides, or other types of resins can be used for these purposes. Some silicones have been used satisfactorily up to temperatures above 600°F, but everyone can tell you that we need to increase this temperature limit. We deal here with very complex molecules and we have learned to vary the mechanical and electrical properties by combining several thermosetting resins to form plastic "alloys" and by engineering new molecules. For example, it is possible to obtain a lithium-alumina silicate which exhibits a constant unit expansion with varying temperature. Special plastics can be created to have thermal expansion coefficients which match those of metal. This is important for example, in high speed rotating electrical machinery; hence it is necessary to maintain gaps and clearances between rotor and stator at approximately constant value even though the temperature of the machine changes during operation. In this manner it is also possible to select the dielectric constants of plastics by using different filler materials such as titanium oxide in a polyester resin. These are but a few of the examples of how improved plastics can materially aid our electrical and electronic capability in many military devices, i.e., missiles, satellite communications equipment, high-power, high frequency radar, space-borne computers, and others. We need to push the physical, chemical and electrical properties of these plastics to the limits of the environment found in new weapons systems.

One of the missions which the Advanced Research Projects Agency has been given concerns the development of future possible weapons that use space as their operating environment. This includes management and control in cooperation with the military services over the development of such devices as communications satellites, navigation satellites, research space vehicles, ballistic missile defense devices which operate in space, and many others. The new environment of outer space is indeed a challenge to the designer, the scientist and the engineers who are concerned with these vehicles. This unusual rarified environment imposes new requirements on materials and chemicals that have to withstand this strange exposure. Let me give you a few examples which are typical of this new environment. For example, we find the high vacuum in outer space does not permit the use of materials which evaporate quickly, to be applied on the outside of the vehicle. These materials cannot be a part of the permanent external structure of the vehicle because they would disappear. This therefore, puts a premium on materials with low vapor pressure.

Also, we have learned that highly polished mating surfaces without lubricants cannot be moved in a vacuum. Air between the surfaces normally acts as a lubricant and there is no air in space. Thus, we have to devise new methods for providing lubrication for rolling and sliding machinery contacts in a vacuum. How this will eventually be accomplished we do not know at this time. A surface layer of molybdenum can act as a lubricant in space provided the temperature is not high.

The strong ultraviolet radiation in space has its effect on many organic compounds. Some of the plastics have the tendency of changing their molecular structure and hooking together additional atomic bonds between molecules when exposed to ultraviolet light. This can be particularly important to paint which covers the outside of the space vehicles because it is possible to change the emissive characteristics of such paints when the chemical composition is changed. This affects directly the thermal balance of the space vehicle and may cause the internal temperature to rise slowly or fall depending on the change in this discoloration and thus the emissivity of the surface covering. Certain solar energy conversion devices could be more easily devised if a transparent plastic could be made which remained unchanged for a period of a year or two while in space with the attendant ultraviolet irradiation. Therefore, there is a premium on those kinds of paints, plastics, covers or paint binders which do not exhibit a sensitivity to strong ultraviolet radiation over long periods of time.

There is a problem of the erosion by micrometeorites and the problem of withstanding various types of radiations ranging from electron and proton bombardments to X-ray and corpuscular radiation such as cosmic rays. Some of the nuclear radiation in the laboratories have produced polymerization in certain organic compounds. Certain radiations in space may have similar effects and may cause changes in molecular structure of several organic materials.

A veritable revolution is occurring at present in the field of energy conversion and power sources. Conversion of heat directly into electricity by means of a temperature gradient in a variety of semi-conductors is being developed along a wide front by the Department of Defense. Compounds such as Lead Telluride, Bismuth Telluride produced under very high purity conditions and carefully doped, have led to some remarkable power devices already. A great search is in progress to develop a host of compounds which will possess a high Seebeck coefficient and a high electrical conductivity coupled with a low thermal conductivity. Conversion of solar energy by means of silicon-boron solar cells is our only means of providing a long life power supply for satellites at the present time. A strong effort is being made to improve this technology. For instance, the aid of a chemical concern, with expert process technology capability, is being used to possibly grow large thin single crystal sheets of silicon where heretofore we have had to cut small flakes (1x2 cm) out of cylinders. Our ambition is to make flexible carpets of photosensitive materials to convert solar energy to electricity for our satellites. Other photovoltaic materials being developed are gallium arsenide, allium phosphide, indium phosphide, Cadmium sulphide, Indium antimonide, Cadmium Telluride, etc.

We would like new ideas for chemicals which can be disassociated efficiently by photolysis and pyrolysis and whose products then can recombine in a fuel cell to produce electricity. In this way we could have a complete chemical system energized by the sun for our space stations.

One of the areas in which ARPA is particularly interested concerns the many challenging chemical problems in the upper atmosphere. There seem to be a wide variety of relatively simple chemical reactions

*(Continued on page 53)*

# NAVY REQUIREMENTS OF THE CHEMICAL INDUSTRY

By

**Rear Admiral K. S. Masterson, USN**

*Assistant Chief of Naval Operations (Development) and Director, Guided Missile Division*

It is a distinct pleasure to be here this morning. Those of us that are charged with guiding the Navy's Research and Development program keenly realize that the efforts of science and industry linked to our own efforts are carrying us toward very significant improvements in the future Navy—in vehicles—in weapons, and in intelligence systems. The glamorous chase of these alleged "break throughs" seems to lodge with almost anyone but the chemists. However, when we face the sobering fact of translating new ideas into real capabilities in adequate quantity, we realize that the chemical industry is always there providing materials, fuels – propellants—a whole multitude of critical components improved or newly created to support the gain.

Rather than attempt to describe the Navy's requirements of the chemical industry in terms of numbers and bulk of the thousands of items we use, I feel it more appropriate to point out some areas in which the Navy requirements are peculiar to their naval employment.

Our operating medium is shipboard. Most particularly, our most demanding operations occur in the confinement of submarines. Much of what I am going to say could be directly translatable to other sealed vehicles such as space vehicles– however, let us face our existing problem in submarines. Both in missile propellants and in primary fuel cells it appears that maximum impulse or energy conversion could be obtained from the cryogenic systems such as hydrogen and fluorine or hydrogen and oxygen. The storage problems involved and the toxic threat posed by such systems lead us to alternatives such as solid propellants or solid sources for gases. The problem posed to the chemical industry is "How close can we come to the impulse or energy conversion of the cryogenic systems and still meet the environmental limitations of Navy operations?" Through liaison with industry—ONR, the laboratories and the bureaus keep industry aware of specific problems in this area. These include stability under various conditions of temperature and other environmental factors, attack on containers and stability in the presence of practicable containers and probable contaminants. These are similar to the questions that the chemical industry must answer for its civilian market, *except that* the term of storage and the permissible levels of toxic gases are generally more stringent than the industry requirements elsewhere.

I mentioned primary cells a moment ago. These are a most interesting source of electrical energy to the Navy. The elimination of rotary converting equipment and/or air breathing engines is a most desirable feature in any ship but it is most particularly of interest in submersibles. Although some practicable devices can now be reduced, we believe that this field can be profitably pursued to obtain a larger value of kilowatt hours per pound from substances which are more compatible to the environment.

Admiral Masterson has been associated, throughout his naval career, with both practical and technical phases of weapons systems.

In his current assignment, as Director of Guided Missiles, he is responsible for guiding, coordinating, and evaluating the development and employment of guided missiles and related devices; and is Executive Member of the Navy's Ballistics Missiles Committee, headed by the Secretary of the Navy. In addition, Admiral Masterson has been designated Assistant Chief of Naval Operations (Development).

When the Japanese attacked at Pearl Harbor, on 7 December 1941, Admiral Masterson was assigned to the battleship *Arizona,* one of the vessels which was sunk on that occasion. Shortly afterward he was transferred to the USS *Pennsylvania* to serve as Assistant Gunnery Officer, and, later, Gunnery Officer.

Before reporting for his present assignment, Admiral Masterson served as Commanding Officer on the USS *Boston,* one of the Navy's guided missiles ships.

A similar naval interest is the area of thermo-electric devices which are now approaching a competitive position. The problems in employment of the thermoelectric devices are not yet as well defined. However, it seems probable that their efficiency, storage character and toxicity will greatly influence their ultimate desirability.

With all of the complex systems proposed or in development for naval use, the necessity for extensive

automation has become increasingly apparent. This is largely an electronics problem as we now see it. Our experience also tells us that devices such as transistors or photo detectors may start life as metallic elements obtained by the experimental physics techniques and end up in real production and use after a transition to chemical deposition techniques. The very promising micro-miniaturization programs may provide for data processing and automation in remarkably small volumes and at low power. However, the cost of these small modules may be excessive if they cannot be produced reliably in large numbers by simple technique.

Another problem area in the utilization of man in a closed environment is that of providing him with oxygen, water and food. The feasibility of using photosynthesis has been established. However, the bulk and weight of the devices so far conceived has been excessive. Consequently we are using air washing and replenishment cycles generally involving inorganic chemicals. They do not produce food or potable water. The extent to which these devices provide a vital human environment may well determine the efficiency and the voyage duration of our deployed submarine forces. Associated with this problem are requirements for paints, paper, lubricants, hydraulic fluids, fire fighting materials, insulation and a whole regiment of materials which must be compatible with enclosed humans and the system which maintains the human environment.

I have talked in rather general terms of our Navy requirements. Before closing I would like to give you the names of some of our offices and agencies that can help you with defining Navy requirements on specific problems.

The Material Bureaus, primarily Bureau of Ships and the new Bureau of Weapons have sections dealing with materials and logistic problems and also research divisions.

The Office of Naval Research has chemistry branches in the Materials Sciences and the Biological Sciences divisions. There are in addition five ONR Branch offices located as follows: Pasadena on Green Street, San Francisco at 100 Geary Street, Chicago in the John Crerar Library, Boston in Naval District Headquarters, Summer Street, and New York at 346 Broadway.

We have some field stations with various competencies, namely: Naval Ordnance Test Station, China Lake, solid propellants; Naval Ordnance Laboratory, White Oaks, explosive research; Naval Air Material Center, Naval Base, Philadelphia, for aircraft components and radiation testing; Materials Laboratory, New York Naval Shipyard, shipboard materials generally; Norfolk Naval Shipyard, paints; Naval Clothing and Textile Office, Philadelphia.

The Deputy Chief of Naval Operations, Development, usually referred to as OP 07, is always interested in hearing of new developments and applications.

Gentlemen, we are confident that the chemical industry is progressive and competent. We are anxious to provide the liaison that will insure that our needs are known to you. We must!—for of all the services and other customers we *live* with our fuels, munitions, and the other chemical products which make up a fighting Navy.


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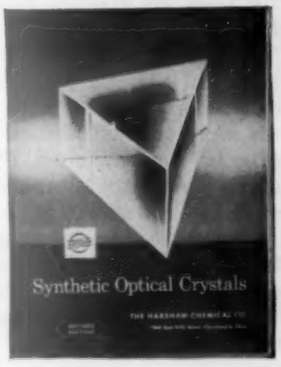


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# MARINE CORPS REQUIREMENTS OF THE CHEMICAL INDUSTRY

By

**BRIGADIER GENERAL G. R. E. SHELL, USMC**

*Deputy Chief of Staff, (R&D)*

*Hqrs. U.S. Marine Corps*

I AM PARTICULARLY pleased to have this opportunity to talk to you about the Marine Corps and our requirements of the chemical industry. Today I propose to cover some of the areas in which you can be most helpful.

The common picture of a Marine is a man in a fancy blue uniform or a man in a muddy helmet, carrying a pack and a rifle. However, despite these stereotypes, Marines have an extremely varied and versatile character which calls for the most modern equipment in order to fulfill our part of the national defense mission in the Twentieth Century.

As you know, the primary mission of the Marine Corps is to provide Fleet Marine Forces, consisting of ground and air units as elements of the balanced fleet, to conduct amphibious operations. A second mission is to develop the landing force tactics, techniques, and equipment required by the landing forces in amphibious operations. We also have our historic mission to perform such other duties as the President may direct. This last responsibility keeps us on our toes, with many interesting possibilities. From our mission we derive our role as a force-in-readiness to deter or to meet limited war situations as they may arise in widely separated parts of the world.

In recent months there has been a growing realization among leaders in government and among the general public that the catastrophe represented by the threat of nuclear war makes limited aggression the more likely situation than all-out war. World events of the past few years have reflected this pattern of creeping aggression. All we have to do is reflect on Korea, Indo-China, and now, Laos. While all-out assault against the United States remains as the greatest danger, it is the bit-by-bit loss of the free world to limited and the more subtle type of aggression that constitutes the greatest long-term threat to the nation's security.

The Marine Corps is the traditional and historic implement of our sea power when limited United States' aid or intervention against an aggressor is needed. Marines were in this business long before the term "limited war" was invented. As part of the balanced and mobile fleet, our Marines are ever ready to support national policy and to protect Americans.

In response to these varied missions and responsibilities, we feel we have maintained a balance in our concepts and the organization of our modern Marine Corps. We are designing and equipping ourselves for both the atomic battlefield and the small "brush fire" war.

Together with the Navy, the Marine Corps has developed a new doctrine for the employment of our forces, in the event of war—limited or otherwise. This doctrine exploits the speed, versatility, and flexibility of the helicopter.

Inherent in the doctrine is a concept of vertical envelopment which uses large numbers of helicopters for the movement of troops from ships to shore in the amphibious operation. We avoid the enemy defenses and land our forces in separated areas on his flanks and in his rear. We stress speed and mobility by air, ground, or sea for rapid concentration on the objective and speedy dispersal of units.

This new doctrine has had a major impact on the orientation of our materiel research and development efforts. While previously all of our forces moved from ship to shore in landing craft, our fighting units now will be transported by helicopters and other VTOL aircraft, and lighter equipment must be packaged for this

General Shell is now serving at Headquarters of the U. S. Marine Corps as Deputy Chief of Staff (Research and Development). A veteran of Guadalcanal, Tarawa and Saipan campaigns of World War II, his outstanding service as a Marine artillery commander earned him the Legion of Merit with Combat "V."

General Shell was born October 20, 1908, at Phoebus, Virginia; is a graduate of Virginia Military Institute, and has a degree of Bachelor of Science in Electrical Engineering.

Severely wounded in World War II, General Shell, following his return to the United States in 1944, was treated for almost two years at the Naval Hospital in San Diego. Afterward he attended the Naval War College and was retained there as instructor. Among his other postwar assignments was duty as Staff Planning Officer, Plans, Policy and Operations Division, Supreme Headquarters, Allied Powers, Europe.

He was promoted to his present rank in July 1956.

type of transport. I don't mean lighter in the sense of a few pounds; the overall savings of weight in a fighting unit's gear must be in tons—savings in tons both for the weapons and equipment used, and for the supplies and logistical load which supports the fighting Marine and his weapons.

This objective is doubly difficult to attain because as we are attempting to increase mobility by lightening our load, at the same time our units, now smaller and more widely separated, must have increased striking power.

These two problems of greater striking power and lighter loads appear as divergent objectives. However, we must bring these paths together if we are to maintain supremacy on the modern conventional battlefield. The burden of merging these goals rests on major advances and applications in the technical sciences, principally the science of chemistry.

To pinpoint some of our efforts and problems, let's look first at the equipment for the most important and final weapon on any battlefield, the individual combat Marine. Despite new concepts of warfare, his job *now* is what it always has been—to close with the enemy and to seize and occupy the ground. And, despite the advances in transportation, he goes into a fight on his own two feet.

Let us look at this man and his individual problems. What equipment does he need in order to carry out his job of disposing of the enemy and to survive on the modern battlefield? To survive he first must be armed, clothed, and fed. As he closes with the enemy he has to be protected in order to bring his weapons into operation and, finally, he must have an effective and superior means of killing his opponent.

In the initial stages of an attack all of these items must be carried by the man, and therein lies one of our first problems of reducing weight. As many of you well know from experience and we certainly have studies to show that this Marine (who must do the actual fighting) should not be required to carry more than fifty pounds on the march or twenty-five pounds in combat if he is to function effectively. More weight than this, and the man's fighting efficiency drops off drastically. Ideally, we would like him to carry no more than thirty pounds at any time. However, as modern warfare has become more complex, and nuclear, chemical, and biological warfare demand additional items of equipment, the problem of reducing weight has increased in importance.

One of the recent examples of progress in the area of protecting the Marine from the natural elements is through the use of artificial fibers which have reduced the weight of the Marine's shelter tent, sleeping bag and air mattress combination from approximately fifteen pounds to five pounds, and we would like to get it lighter. Ten pounds appears to be a small item, but when it is realized that almost 100 tons will be taken off the backs of a Marine Division, it is a tremendous overall saving.

Since the Marine must carry water, we, along with the Army, have pursued the improvement of the canteen. A plastic canteen is now under development which is not only lighter but is less likely to injure the Marine while moving and fighting.

In the field of food products, in order to lighten the load of the food and rations the Marine must carry, we would like to see the development of a good packaged ration that could be eaten without any need of mess gear which he must carry now. There is also a demand for a good flameless heating element to warm his rations in the forward areas.

Individual weight savings on items in the Marine's load need not be great in order to add up to an impressive total saving that will permit him to operate at maximum effectiveness in the fast-moving, highly-mobile warfare envisioned in our modern vertical assault doctrine.

One area which should be explored much more extensively is the field of inexpensive, disposable equipment; equipment that could be easily destroyed when no longer needed. As it is now, there are too many things that Marines have to carry in for an operation and then pick up, usually empty, and carry out again. Most of these items are those that are necessary for the simplest survival of the individual—mess gear, water cans, ammunition belts, tents, and other field equipment that does not kill.

To protect the Marine and keep him alive on the battlefield, armored vests made of plastic and fiber glass proved their value in Korea. However, there is still plenty of room for improvement on the armored clothing we have today. The ballistic properties of the armor have been improved, but there has been no technological break-through to reduce the weight of the materials constituting the armor. As it is, the armor the Marine wears is still too heavy (8-10 pounds) and too hot and uncomfortable. I will add that no one is throwing the armored clothing away when shots are fired in anger.

In addition to body armor, operations in a nuclear environment require individual Marines to carry warning devices such as dosimeters or film badges and radiac instruments. Each of these items, necessary as it is, adds to the load of the man who must fight.

Your industry can make a valuable contribution by developing lightweight but adequate materials to keep the individual load limit within bounds. Lightweight but durable clothing protects the combat Marine. In combat disposable clothing would be a big step, and I know work is going on in this area. It would be highly desirable if this same clothing could protect him in nuclear, biological, and chemical warfare.

For the task of fighting and stopping the enemy, we will always need to develop lighter and more lethal personal weapons.

Moving from the load of the individual Marine to the supporting field—new, light, strong metals are the demand in transportation, the heavier support artillery, missiles, and communications. Our requirements are: simplicity, ruggedness, reliability, and economy. All of our transportation is too heavy with the exception of the Mechanical Mule and the Mighty Mite. We need precision tube-type weapons of light weight materials in artillery, and we have a great demand for silent power sources for radios and telephones.

In the area of combat support, our bulk fuel handling system is a good example of how the chemical industry has helped us to reduce a major logistic problem. The requirements for bulk fuel for a Marine Division-Wing team in an amphibious landing are tremendous. The adaption of rubber tanks and flexible pipelines permitting ship tankers to pump the oil directly into a field storage farm has accomplished a great saving in material that must be shipped to the area of operations as well as saving countless man hours.

But existing fuels still create problems of weight and bulk. Research aimed at the development of fuel of less weight and bulk than our present fuels and lubricants could enhance our capabilities tremendously.

In an area closely allied to bulk fuel handling, we are following the development of a lightweight, expend-

# NAVAL BASIC RESEARCH IN PLASTICS

By

**DR. L. W. BUTZ**

*Office of Naval Research—Navy Department*

THE NAVY, through the Office of Naval Research, is supporting a modest program of basic research in plastics which can be regarded as being in two fields, first, research in the correlation of structure and properties and second, research in the synthesis of new plastics. I shall present this program without reference to the development programs of other Naval activities which, I believe, are better known to the industry. For example, the requirements of the Bureau of Ships for high temperature dielectric materials are widely known.

The objective of the basic research program is to accumulate new knowledge useful in the later development of plastics that can be fabricated and employed above 1000°F. One object is to develop information concerning the range over which properties can be varied by variation of details of structure. Another is to provide new inorganic plastic compositions.

In the first field the Mellon Institute, the University of Massachusetts, the Hughes Aircraft Company, and Princeton University are cooperating with the Office of Naval Research. In the second the Pennsalt Chemicals Corporation, the Hughes Aircraft Company, the Stauffer Chemical Company, and the National Bureau of Standards.

The potential outlets for inorganic plastics appear to warrant an increase in the size of the present Navy basic research program. A part of this research should be done in industrial laboratories where scientists are available who are outstanding in the several science fields and where there is a degree of stability in retaining personnel that would make a four to five year project possible. Since this is basic research and since important results are best assured by an organization vitally interested in the subject, the Office of Naval Research urges that such projects be jointly supported by the proposing organization and the Navy. No proposals, however, will be declined solely on the ground that they do not include this feature.

The basis for sponsorship of a research by the Office of Naval Research is a written proposal by the persons who desire to do the work with a budget and approval by management. Our great need is for acceptable research proposals. The science part of the proposal is addressed to chemists and physicists who may not be specialists in the particular fields, plastics and inorganic synthesis. It looks like a paper for a journal, or rather a combination of two papers—one a critical review of current relevant knowledge followed by the other, a report of original work containing everything except the results. The objective, the chemical range, the probable duration, and detailed experimental plans for the first six months of the proposed contract are clearly described. If the proposal has the indicated degree of completeness, definite action on it is usually possible in less than six months.

Some research areas not covered in the present program will be discussed.

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Many A.F.C.A. members will remember Dr. Butz as one of the speakers at the 1957 meeting of the Association, in Washington, D. C., when he appeared as coordinator of the Navy's part of the technical program.

Dr. Butz has a background of continuous service in chemical research since 1936 when he joined the Department of Agriculture. For ten years he was a research chemist at the Department's Experimental Station in Beltsville, Maryland, and since that time has been head of the Chemistry Branch of the Office of Naval Research.

Dr. Butz was born in Cressona, Pennsylvania, in 1906. He was graduated with a Bachelor of Science degree at the University of Pennsylvania in 1927 and received his Doctor of Philosophy degree from the University of Illinois in 1933.

During the past five years Dr. Butz has been connected with the Navy's program of research on the synthesis of high temperature resistant elastomers and plastics.

## MARINE CORPS REQUIREMENTS

*(Continued from page 17)*

able five-gallon cardboard fuel container with a plastic liner. Conceivably, this item could replace the old five-gallon expeditionary can familiar to many of you. This is an example of the type of item that we carry into the battlefield but can be thrown away after use.

The Marine Corps, of course, is following with close interest the developments of the novel non-lethal chemical warfare agents of which all of you have read in the press—agents which deter men from accomplishing their tasks but do not maim or kill. These agents could be a very effective limited war weapon. However, whether or not such items are ever used in warfare, we must possess effective defenses and protection from these as well as the conventional chemicals that may be employed.

Gentlemen, in conclusion, I want to emphasize that in this brief time I have not attempted to discuss all of our research and development problems. We certainly have many needs in the areas of so-called "glamour" weapons such as missile, aircraft, and electronic systems. However, because the needs and problems of these "glamour" weapons are more commonly known, I have purposely emphasized our needs in the less glamourous but essential areas that are so often overlooked.

We are always striving to develop more efficient equipment for our use, and we look to the chemical industry to continue to make tremendous forward strides, enabling the Marine Corps and the other services to stay ahead of all possible opponents and to keep the United States armed services the best equipped in the world.

## 14TH ANNUAL MEETING

*(Continued from page 10)*

ally the case following the regular spring meeting of the Board prescribed by the Constitution. It is to be noted, however, that following receipt of certain new proposals for Achievement Awards by the Association, the Board, after discussion, directed the Chair to appoint a committee to study the whole question of Achievement Awards, including the current Science Teacher Award, and voted to discontinue all such awards in the future pending the receipt and consideration of the committee's report.

### The Annual Banquet

The annual banquet for the meeting, held the night of September 11, was in all respects a gala affair in accordance with best traditions of the Association. There were a large number of distinguished guests seated at the head table. including a number of ladies. These were Mrs. Annie Sue Brown, this year's Science Teacher Award winner, and wives of several of the dignitaries present.

The banquet proceedings were opened by Meetings Chairman, Mr. Donald MacArthur, who introduced Brigadier General Clifford L. Sayre, President of the Association, as the Master of Ceremonies for this occasion. General Sayre, after introducing the distinguished guests, read a telegram of greeting from President Eisenhower, and also felicitations from Secretary Franke of the Navy, Secretary of the Army Brucker, General Pate of the Marine Corps, and Admiral Mendenhall, Commandant of Potomac River Naval Command. These communications are printed herein.

Before introducing Mr. Sutton, the banquet speaker, President Sayre called upon Dr. Ralph E. Gibson, former A.F.C.A. vice-president, who is Chairman of the Science Teacher Award Committee, to present the Association's 1959 Science Teacher Award. Dr. Gibson spoke of the great importance of secondary schools science teachers or supervisors, stating they are the members of our educational system on whom the nation largely relies to inculcate interest of pupils in science subjects. He praised the outstanding work of Mrs. Brown, this year's recipient of the award, as science curriculum specialist of the school system in Atlanta, Georgia, noting that her selection by the committee was unanimous. He then presented to Mrs. Brown the Association's award, a check for $1,000 and accompanying certificate. Mrs. Brown made a short speech of acceptance, expressing her gratitude to the Association and the great pleasure which her visit to Washington to receive the award had brought her.

### Head Table Seating

THE head table seating was as follows: Mr. Donald MacArthur, Koppers Company, Inc., (General Chairman; Mrs. Charles E. Waring; Rear Admiral Rawson Bennett, Chief of Naval Research, United States Navy; Mrs. G. R. E. Shell; Major General Marshall Stubbs, Chief Chemical Officer, United States Army; Mrs. W. T. Thurman; Rear Admiral W. K. Mendenhall, Jr., The Commandant, Potomac River Naval Command; Mrs. George P. Sutton; The Honorable C. P. Milne, Assistant Secretary of the Navy (Material); Mrs. A. G. Trudeau; Mrs. Clifford L. Sayre; Mr. George P. Sutton, Chief Scientist, Advanced Research Projects Agency; Brigadier General Clifford L. Sayre, President Armed Forces Chemical Association; Mrs. C. P. Milne; Lieutenant General Arthur G. Trudeau, Chief of Research and Development, United States Army; Mrs. W. K. Mendenhall, Jr.; Major General W. T. Thurman, Assistant for Production, Deputy Chief of Staff, United States Air Force; Mrs. Marshall Stubbs; Rear Admiral G. A. Rosso, Chief of Chaplains, United States Navy; Mrs. K. S. Masterson; Brigadier General G. R. E. Shell, United States Marine Corps; Mrs. Donald MacArthur; Rear Admiral K. S. Masterson, Assistant Chief of Naval Operations, (Development); Mrs. Annie Sue Brown, Curriculum Specialist in Science, Atlanta Public School System; Dr. Charles E. Waring, Department of Chemistry, University of Connecticut.

Musical entertainment was provided at the banquet by the Navy's noted choral group, the Sea Chanters.

Appreciation was expressed at the meeting by President Sayre of the generous contributions received from the following member concerns:

Allied Chemical Corporation; American Cyanamid Company; Bechtel Corporation; Blaw-Knox Company; Celanese Corporation of America; Dow Chemical Company; E. I. duPont de Nemours & Company, Inc.; Esso Research & Engineering Co.; Fisher Scientific Company; Food Machinery & Chemical Corporation; General Tire & Rubber Company; Hooker Chemical Corporation; Koppers Company, Inc.; Arthur D. Little, Inc.; The Lummus Company; Olin-Mathieson Chemical Corporation; Merck & Company, Inc.; National Lead Company; Chas. Pfizer & Company, Inc.; Shell Chemical Company; Stauffer Chemical Company; Sun Oil Company; and Union Carbide Corporation.

### Exhibits—Including Fine Art

A large anteroom leading to the banquet hall at the Statler-Hilton, where the meeting sessions were held, was made use of for display of exhibits by the various Armed Services. These portrayed many different activities of current interest—Naval, Marine, Air Force, missile operations, medical services, etc., as well as gas masks and other displays of the Army Chemical Corps.

An unusual and much appreciated feature of the exhibits this year was the display of paintings, water color and oils brought over from their accustomed hanging place in the Pentagon for the benefit of A.F.C.A. visitors. These included work of artists Beaumont, Haun, Murray and Wilber.

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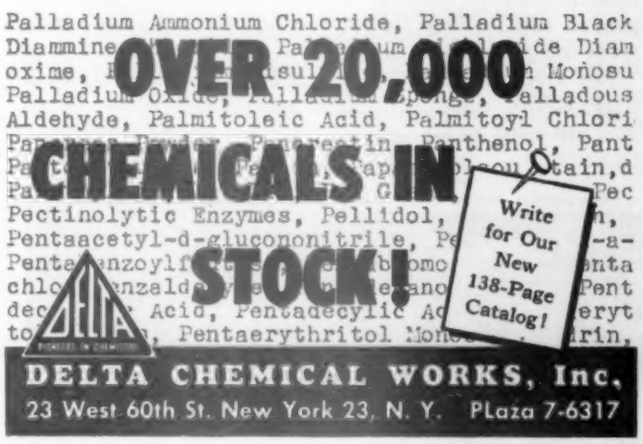

# THERMAL GENERATION OF ELECTRICITY AND THERMOELECTRIC HEAT PUMPS

By

**COMMANDER BRYCE D. INMAN, USN**

***Bureau of Ships—Navy Department***

THESE TWO little slugs of material are the working parts for an engine generator. This is a demonstration model of an ice machine—also no moving parts. These are thermoelectric materials which are the products of research in a new and exciting field of energy conversion.

The Navy has always been alert to the possibility of early utilization of technological break throughs. Radar and nuclear propulsion are examples. We may be on our way toward a breakthrough in thermoelectricity. For this reason, I am delighted to have the opportunity to tell you something of the Navy's thermoelectricity program. First, perhaps, I had better spend a little time telling you what thermoelectricity is, what it will do, and why the Navy is interested in it.

Thermoelectricity may be broadly defined as the interaction of heat flow and materials to produce electricity, or the reverse effect, the interaction of electric current flow and materials, to pump heat.

In 1821, Thomas Johann Seebeck observed the deflection of a compass needle held near a circuit containing two different materials through which heat was flowing. Unfortunately Herr Seebeck thought he was dealing with a magnetic effect in the material, and although he investigated a large number of materials we now call semi-conductors, he never realized that he was generating electricity. In theory, with materials he knew, he could have built a generator with an efficiency at least as great as the first steam driven dynamo which was not built until a half century later.

In 1834, thirteen years after Seebeck's discovery, Jean Charles Peltier, a French watchmaker, discovered a thermal effect when a current was passed through the junction of two dissimilar metals. He too misinterpreted his observations and concluded he had found an exception to Ohm's law. In 1838, Emil Lenz froze a drop of water at the junction of two materials by means of an electric current passing through these materials. This proved conclusively that heat was being pumped away from the junction by the current.

For a century the Seebeck effect was used only as a temperature measuring technique. The Peltier effect was not used at all.

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Commander Inman received a commission in the Naval Reserve in 1943, following graduation from Ohio State University with a Bachelor of Chemical Engineering degree. After attendance at various Service schools, he was assigned to the Naval Research Laboratory, and in 1946 was commissioned in the Regular Navy and designated an Engineering Duty Officer.

He is a graduate of the Navy Postgraduate School where he was awarded a Bachelor of Science degree in Electrical Engineering and a Master of Science degree in Engineering Electronics.

Following this schooling, Commander Inman was assigned to the San Francisco Naval Shipyard where he served in the Production and Planning Departments. Service in Guam and later in the Department of Defense as Technical Advisor on the staff of the Comptroller of the Department followed. He is now a Projects Officer in the Electrical and Electronics Branch of the Ship Design Division Bureau of Ships.

We now have efficient steam turbogenerators and internal combustion engine driven generators. Millions of motor driven compressors operate in air conditioners and refrigeration machines. What, then, are the advantages of this new technique? Why is the Navy devoting considerable R and D effort to the program? The prime advantage of thermoelectricity is its simplicity. In a steam turbogenerator, the heat is transferred to the steam, which drives the turbine, which in turn drives the generator, often through a set of reduction gears. After the steam is condensed, the condensate is pumped back to the boiler for another round trip. Conceptually, this is certainly the hard way to do the job. By contrast, we can visualize a fire box lined with thermoelectric materials instead of fire brick. The inputs to such a heat engine would be fuel and air. The direct products would be smoke and electricity.

Most of the advantages of the thermoelectric generator stem from this basic simplicity. We believe that reliability and reduced noise generation will be the natural result. Both silence and reliability are qualities the Navy is willing to pay a premium for. It is even conceivable that the thermoelectric generator will be less expensive. Two additional advantages of great importance to space and other special applications are the small size and weight of the minimum generator and the absence of moving parts. The latter is particularly important in space applications where inertial effects are of major importance. These two slugs of material the size of pencil erasers constitute a basic generator having an output of about one watt. A practical conventional engine generator for this power level is almost inconceivable.

The Peltier heat pump offers the same sort of advantages. Like the generator it is expected to be reliable and silent. The small size of the basic unit and the fact that it can pump heat in either direction, depending only on the direction of current flow, makes this technique valuable for localized temperature control.

These are the advantages. Why then, are we not building thermoelectric generators rather than turbines? The problem is our incomplete information about materials. As I mentioned earlier, some materials available in the 1820's were capable of a theoretical maximum conversion efficiency of about 3%. A century later, our typical thermocouple temperature measuring instruments were capable of a maximum conversion efficiency of only $\frac{3}{10}$ of 1%. Recently semiconductors were rediscovered. These materials, cousins as it were, of the materials which have made the transistor a reality,

are the key to thermoelectricity, both power generation and heat pumping. In just a few years the material conversion efficiency has been pushed from a few percent to over 15%. At this value many special purpose devices look very attractive. If this value can be pushed to 20 or 25% it will be a major breakthrough. Much over this value could mean an explosive reorientation of our whole concept of power generation. However, we may never reach either of these levels. It is still too early to make a valid prediction either way. There is a tremendous amount of materials work to be done. We have to learn a great deal about such uncommon compounds as bismuth teluride and indium arsenide. Once we have produced the material with the required figure of merit, our work has just begun. There are a staggering number of problems to be solved before a good material can be used for a good generator. The simple problem of attaching electrodes to these little slugs of exotic material in such a way as to prevent the electrode material from contaminating the thermoelectric material is no small problem, demanding the best efforts of chemists, physicists, metallurgists and engineers.

Once feasibility of a large oil fired generator is established it is only natural to look to radio isotopes or a reactor for the heat source. This attractive combination raises a whole new family of problems as these new and relatively unknown materials are subjected to a radiation environment.

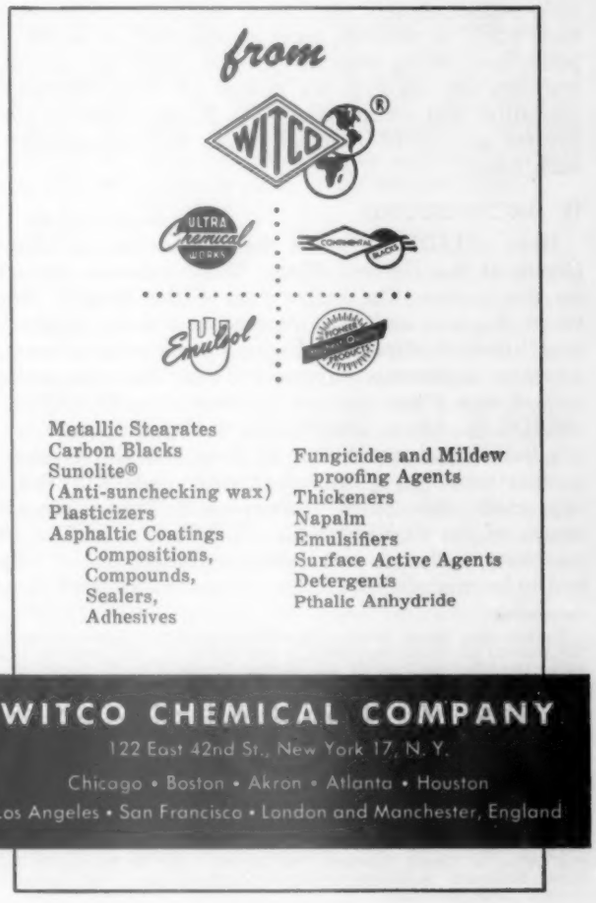
Do I sound pessimistic? I don't mean to. Actually we are very optimistic about the future of thermoelectricity. We believe that even if the phenomenal rate of progress in conversion efficiency of materials were to stop this afternoon and we never advanced a bit farther, we would have to abandon the idea of powering ships this way, but there would be enough special purpose applications to justify all of the effort which has been expended.

Actually many of you have a thermoelectric generator in your houses now. It is the fail-safe device which shuts off the gas when the pilot light goes out. Last year President Eisenhower unveiled in his office a small power plant for space applications. This was a battery of thermoelectric elements heated by a slug of radioactive materials. This unit weighs 5 pounds and has no moving parts. While it produces only 3 watts, it will do so for the better part of a year. It would take ¾ of a ton of batteries to supply the same total energy. Some time next year Bureau of Ships contractors will deliver two models of a 500 watt generator. If the specifications are met, and there is no reason to believe that they will not be met, this generator will weigh about 35 pounds, will make about as much noise as a gasoline lantern and can be started with a match. When this is compared with the comparable gasoline engine driven generator, we find that the latter weighs some 60 pounds, is noisy at best, and can be very temperamental on a cold day. With more development this sort of a device can fill a very real need in the Armed Services. Economics will probably delay its introduction into the civilian market. Next year, also, the Bureau of Ships will take delivery on two oil fired 5 Kilowatt thermoelectric generators. These units should be almost as efficient as a small gasoline engine generator. They are not aimed directly at a military requirement. Rather, they are a step toward a full size shipboard generator which will have a capacity of at least several hundred kilowatts. An interesting feature of one of these generators is that its output is 440 volts, three phase 60 cycles even though the basic thermoelectric generator, of course, supplies direct current. The conversion from DC to AC is made with semi-conductor devices.

The Navy is also working on a number of thermoelectric heat pump developments. This application of thermoelectricity will probably be the first to appear on ships. We are working on a small constant temperature box for critical electronic components. Heretofore such a box was an oven to which a variable amount of heat was supplied. With thermoelectric elements we can pick a temperature and pump heat in or out to maintain that temperature. The temperature can even be considerably below the ambient.

Three Bureau of Ships contractors are engaged in studies and component development for a shipboard air conditioning and refrigeration system. With present materials these systems will not be as efficient as our present compressor systems, but they should be silent and trouble free.

In summary we can clearly visualize important special purpose military applications for thermal electricity. Large power generators and heat pumps for ship applications are a bit less clearly visualized and the reactor heated thermoelectric submarine propulsion generator is even further in the future. Materials are the key and the rate of progress in the materials research effort has been nothing short of phenomenal.

# PAINTS, PRESERVATIVES AND COATINGS

By COMMANDER T. B. OWEN, USN
*Bureau of Ships—Navy Department*

*(Note: The 25 lantern slides included in this presentation by Commander Owen contributed much to its interest, but it is believed that the text contains sufficient explanation of these illustrations to make the paper fully intelligible without them.—Ed.)*

## I INTRODUCTION

THE MODERN naval ship is a highly developed complex of structural, machinery, and electronic items and equipment that must operate properly for extended periods of time with a high degree of self-sufficiency. The Navy's requirements for preservation stem from the need for protecting over a period of years the metals, polymers, woods, fibers, and other organic and inorganic materials that make up such a complex from the ravages of corrosion and deterioration. Our problem then is to provide for paints, preservatives, and coatings that will protect material from time of manufacture through periods of shipment, long term storage, and ultimate use at sea against extremes of temperature, pressure, humidity, and a host of other difficult environments.

Navy usage of preservative materials is indicative of our concern with these problems. Annual procurement of shipboard paint for stock runs about 10,000,000 gallons. Although this may seem high, it constitutes less than 0.2% of national paint production. In addition to paint, some sixty separate preservatives and strippable coatings are used in all phases of ship construction, operation, and maintenance. The Navy consumes almost 600,000 gallons of fourteen types of rust preventives each year.

## II BACKGROUND

Here (SLIDE 1) is an aerial view of the Florida Group of the Reserve Fleet. There are also 450 ships on this picture. The active fleet of the Navy is almost twice this size and thus represents a force of eight to nine hundred ships, all of which must receive constant attention in deterioration prevention. Take for example one of our latest aircraft carriers, the FORRESTAL (SLIDE 2). About 100,000 gallons of paint were used in her building alone. When one considers the number of compartments in a typical carrier (SLIDE 3) he can appreciate this paint requirement. The engineering spaces of the FORRESTAL (SLIDE 4) are filled with machinery, piping, and instrumentation, all of which had to be manufactured, test, preserved, shipped, stored, installed, activated and tested, and frequently reserved and reactivated before delivery of the ship. After commissioning there is the continuing requirement for preservation of the operating equipment and the thousands of spare parts stored aboard. Thus we see that the Navy must maintain an active interest in the field of preservation.

## III PAINT

### A. Types

Over a hundred different paint types or colors are used in our warships. These can be classified generally as exterior topside primers and topcoats, underwater anticorrosion and antifouling paints, and interior paints. The last include fire-retardant habitability paints, deck paints, tank coatings, and numerous special purpose coatings. Ship paints are generally made from synthetic resins and mineral pigments. We use vinyls on submarine exteriors, chlorinated alkyds for habitability paints and alkyds for exterior topside paints.

### B. Failures

These are characterized by blistering and rust breakthrough, chalking, wearing, and staining. SLIDE 5 shows the side of a landing ship awaiting maintenance in a Reserve Fleet Group following World War II. In SLIDE 6 is portrayed the failure of the post-pickling primer in a ballast tank. Causes of failure here were inadequate surface preparation, poor coverage on edges and behind stiffeners, dry spray, abrasion, and ultimately breakdown of the paint itself.

### C. Performance requirements

1. General

The varying requirements for paint can be illustrated as they apply on a submarine (SLIDE 7). The external topsides are exposed alternately to long immersions in sea water and to the weather. The undersides are exposed only to the sea and must have antifouling properties. Interior living and working surfaces are coated with fire retardant paints. Tanks are covered with sea water and fuel resistant coatings. Accessible areas near the reactor are coated with paints resistant to nuclear radiation. Acid resistant coatings and linings are used in the battery compartment. Zinc dust coatings are employed in potable water tanks and heat resistant coatings are applied to steam lines underneath the insulation.

2. Special

a. Ice resistance

The weather areas of ships deserve special mention in connection with cold weather operations. In SLIDE 8 we see an ice breaker with heavy ice accumulation and the apparently futile effort of the seamen to remove it. Baseball bats appear to be as effective a means for

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Commander Owen, head of the Materials Development Branch of the Bureau of Ships, not only is the holder of top degrees in science, but, for services at sea during World War II, received the Silver Star Medal, the Bronze Star Medal, and the Navy Unit Commendation, as well as other area service awards.

Commander Owen was commissioned in the Navy in 1940 upon graduation from the University of Washington, with a Bachelor of Science degree in Chemical Engineering. After four years at sea and a brief tour in the Bureau of Personnel, he participated in the Navy's postgraduate training program, and, in 1950, received the degree of Doctor of Philosophy in Physical Chemistry at Cornell University. There followed a year's work at the University of Amsterdam, after which he was designated as an Engineering Duty Officer and returned to the United States to enter the Office of Naval Research. He served later at the Long Beach Naval Shipyard as Assistant Repair Superintendent and Production Control Superintendent.

ice removal as anything. We have investigated many coatings for ice-phobic properties. Most lose whatever initial protection they have when subject to cycles of water immersion, freezing, and thawing.

b. Antifouling paint

These are used to prevent the attachment of marine growths on the underwater surfaces of a ship. The toxic agent is generally a copper compound. Mercury is highly effective but too expensive. Although those paints that are electrically nonconductive and are applied over good anticorrosion coats will not cause trouble some antifouling materials actually accelerate hull pitting. Galvanic corrosion of the hull can take place at breaks in the undercoating because flake or "cement" copper or large additions of conducting pigment act as cathodes to the hull steel. For submarine use black antifouling paint is required. We therefore have to accept the best compromise of copper, copper oxide, and carbon black that will give us the desired color, will prevent fouling, and will not accelerate hull corrosion. The hull of a submarine on which the antifouling paint has ceased to be effective is shown in SLIDE 9. Increased surface roughness due to marine growth causes increased fuel consumption, reductions in top speeds, and is a source of unwanted underwater noise. SLIDE 10 shows the hull of a test ship on which two different antifouling paints were applied. One was effective and the other not.

**D. Need for the future**

We would like to have a universal type of primer over which top coats could be applied as required. It should be readily applicable under shipyard conditions of cold, hot, wet, or dry weather to reasonably well prepared metal surfaces. It should have good adherence and be resistant to sunlight, rain, seawater, common fuels, abrasion, mild acids, and alkalies, and other chemicals encountered in ship operations. The paint would require two coats at most and should cure rapidly when applied. We would prefer that it be solventless but if a solvent were required its flash point should be over 100°F. Such a coating should be available in at least two colors for dissimilarity between coats and the hiding power adjusted so that minimum film thickness for protection is achieved. Available at a reasonable cost it should be serviceable for at least five years under operating conditions. We would use such a material with over coatings of antifouling paint for underwater use, deck paint for additional abrasion and skid resistance. It would serve as a tank coating for fuel and fresh water. We are asking for the moon, perhaps, but we feel that developments in the coatings field may lead to such a paint in the next few years.

## IV PRESERVATIVES

**A. Types**

1. Rust preventives

a. Liquids

Some rust preventives are liquids at room temperatures and can be applied by dip, spray, or brush methods. Most of these materials are petroleum derivatives and include lubricating-type oils, waxes, modified asphalts, and oxidized oils all cut-back in solvent vehicles. One or more additives are introduced to impart peculiar properties. These compounds are widely used to preserve items ranging from the most delicate precision instruments in special storage to large mechanical equipment that may be stored open to the weather. The materials must do more than just protect steel against corrosion. They must be non-corrosive to other metals, miscible with lubricating oil, capable of displacing water, stable to variations in temperature, low in cost, and readily removable.

b. Solids

Other rust preventives are solid at room temperatures and are usually heated to permit application. They are also petroleum derivatives and are essentially petrolatums of varying melting points to which inhibitors are added. Some are transparent whereas others are opaque because of pigmentation. These coatings are used for coating ballast tanks, deck machinery, gun barrels, bearings, etc.

2. Strippable coatings

These fall into two groups that can be differentiated by their physical appearance at room temperature. Those applied cold in liquid form are usually plasticized vinyls, clear or pigmented, and are used with or without corrosion inhibitors. The coatings may be dispersed in special solvents or in water. Hot-applied compounds are solids at room temperature. They are generally cellulose acetate butyrate compounds or vinyl plastisols.

**B. Failures**

These materials are used to preserve critical surfaces of tools, machinery, and parts. Failure is characterized by presence of minor amounts of corrosion and stained areas on these surfaces or on any area where the corrosion products may contaminate the machine or system in operation. They are applied at the point of manufacture and must remain effective until the item being protected is placed in service. Slides to follow show some of the conditions that packaged parts may encounter. SLIDE 11 shows material stored at dockside ready for shipping. In the next SLIDE (12) cargo handling and transfer of material at sea is shown. Note that cargo nets and slings have to be preserved also. A crankshaft and some hand tools that were improperly or inadequately preserved are pictured in SLIDES 13 and 14 which highlight the resulting corrosion. Temperature and humidity in the Marianas Islands act to accelerate corrosion. SLIDE 15 shows material in storage on Guam and strippable coated parts that are in good shape. Equipment on the beachhead established by the Marine Corps in North Korea is shown in SLIDES 16 and 17. The fact that most of this material was salvaged attests to the adequacy of its preservation.

**C. Requirements**

1. Boiler preservation

The inside surfaces of boilers are preserved with a water displacing corrosion preventive applied after proof testing. This compound must preserve the surfaces for periods up to two years under conditions of shed and open storage and then be readily removable so that the boiler feedwater system will not be contaminated when in operation. A boiler being lowered into the FORRESTAL is shown in SLIDE 18. At present we use a hot water solution of sodium metasilicate and a wetting agent for preservative removal. There is need for a material that could be removed by hot water alone to simplify the cleaning of the boiler and the whole feed system. SLIDE 19 shows the condenser shells installed in the FORRESTAL from which preservative must be removed as well. Compounds tested to date are difficult to remove with hot water after they have aged. Oily types of preservatives would be considered if the required protection could be assured.

2. Hydraulic systems

In high pressure systems the Navy has adopted the use of phosphate ester hydraulic fluids. Corrosion preventives used in these systems must be compatible with the fluid and gasketing material used in the lines. Our

*(Continued on page 33)*

# HIGH TEMPERATURE LUBRICANTS

By

**E. R. LAMSON and M. J. DEVINE***

*Naval Air Material Center*

THE LUBRICANTS required for missiles, space vehicles and high performance aircraft are subjected to a variety of operating conditions. These conditions include: extreme temperature range, nuclear radiation and low pressures. To insure adequate lubrication with conventional lubricants, accessory equipment is frequently needed. An example, is the 18 pounds of additional components required to insure lubrication of a single ball bearing for a 5 hour period in one of the latest space vehicles. In an effort to reduce this weight and provide lubricants stable under a variety of conditions, a research program was established by Bureau of Aeronautics.

This program was initially concerned with the development of a specification to cover the conventional dry films being used successfully in aeronautical lubrication. In general, these materials are composed of solid lubricant such as $MoS_2$ or graphite and an organic resin which acts as a binder. A sprayable consistency is obtained by the addition of a thinner. After being applied to the surface of the metal part, the film is cured by baking. Cure time and temperature are dependent on the nature of the organic resin as well as the metal to which the film is applied. These dry films have been limited to plain bearing applications where oils or greases could not be used. It was also considered that ball bearing lubrication could not be afforded by dry films.

In order to investigate this serious limitation, a number of 204 size ball bearings were selected as test specimens. The dry film was applied by spraying at an angle between the ring of the bearing and the retainer while slowly rotating the bearing. After curing, the performance life was evaluated using a standard test spindle. Plate 1 shows the lubricated bearing encased in a housing and positioned on the test spindle. Prior to test, a cover plate is attached and axial and radial leads are applied. The test was conducted at 10,000 rpm. Test results were on the order of several minutes. Results of this type appeared to provide the reason for concluding that dry films were not suitable for ball bearing lubrication. However, the method of preparing the bearing left important factors uncontrolled. These were film thickness, film uniformity and selection of bearing surfaces to be lubricated.

Initial work to suitably prepare a bearing consisted of disassembling the ball bearing into each of its components, applying a uniform dry film coating to the surfaces of the raceways and retainers, curing the coating and reassembling the bearing. Plate 2 shows the unassembled bearing components before and after lubrication. The assembled bearing is shown on Plate 3. A performance life of 4 hours was obtained. A number of films were tried without a significant increase in performance. In order to eliminate the disassembly step, a number of bearings were obtained unassembled. These were prepared as outlined previously. Performance life was increased to 19 hours. When the test temperature was increased to 350°F running time to failure was approximately 3 hours. Varying formulation failed to provide a substantial increase.

Close examination of the bearings revealed that the failure pattern was very much the same in all cases in that the film was completely worn on certain areas of the retainers. In view of this consistent pattern, it was concluded that the organic binder was not sufficiently hard to resist the continual rubbing action of the balls and when rubbed completely off, failure occurred. A number of materials that would form hard films were considered. The soluble sodium silicates appeared most promising. Further, since this material is inorganic, properties such as nuclear radiation resistance and thermal stability should be superior to those of the organic resin binders. Techniques for sample preparation, lubricating formula and cure cycle were investigated. Table 1 shows the performance life obtained at 3 different speeds for an experimental film composed of 55 parts $MoS_2$, 6 parts graphite and 39 parts sodium silicate. The test temperature was 350°F.

**Table 1**

**Bearing Performance**

Apparatus: F.S.T.M. No. 791—(331.1)
Test Temperature: 350°F
Bearing: No. 204 Size—8 Ball, ABEC-1, Standard Radial Clearance .0003 to .0007 in.

| Formula | RPM | Hrs. to Failure |
|---|---|---|
| 23A | 1250 | 240 |
| 23A | 3500 | 42 |
| 23A | 10,000 | 29 |

Non lubricated bearings evaluated at the speeds shown failed in less than 1 minute for the 10,000 rpm run, 3-5 minutes for the 3500 rpm run and several hours for the 1250 rpm run.

At this point, other requirements too extreme for oils,

Mr. Devine is an aeronautical lubrication research engineer in the solid lubricants branch of the Aeronautical Materials Laboratory, Naval Air Material Center. A 1950 graduate of LaSalle College with a degree in Chemistry, he has been employed at AML since 1951. He is chairman of ASTM's subcommittee covering rust preventive tests for lubricating greases, and is a member of the Coordinating Research Council laboratory panel studying bonded dry film lubricants.

* Paper read by Mr. Devine at A.F.C.A. annual meeting, Washington, D.C., Sept. 11, 1959. While the seven plates referred to were not furnished with the text of the paper it is believed the discussion is fully intelligible without those illustrations.—Ed.

greases and conventional dry films appeared within the scope of the experimental films having the sodium silicate binder. An example is ball bearing lubrication in the presence of liquid oxygen, a material frequently used in the propulsion systems of space vehicles. The laboratory apparatus used in conducting such experiments is shown in Plate 4. The liquid oxygen is contained in a 25 liter flask, pressurized gas is used to pump the liquid oxygen through copper tubing to a stainless steel beaker containing the test bearing. The bearing is attached to a shaft which can be rotated at 3600 rpm by means of the drill press motor. Plate 5 shows a close-up of the bearing and bearing housing submerged in liquid oxygen. The test run was continued for 1 hour with a 5 pound thrust load applied. The run was arbitrarily stopped and the bearing brought back to room temperature. After being dried, a 10,000 rpm run at 350°F was conducted. The running time was 21 hours. The running time for the same formulation not subjected to the liquid oxygen run but only to the 10,000 rpm—350°F test was also 21 hours. No comparison with oils, greases or other dry films is afforded due to the possibility of detonation in making runs with these materials in liquid oxygen. A non lubricated bearing failed in 1 minute during a liquid oxygen run. It should also be noted that detonation tests were conducted on the experimental film. The test results showed excellent stability for this material in the presence of liquid oxygen.

The bearings used in the runs so far discussed were fabricated from 52100 steel for the races and balls and 1010 steel for the retainers. In order to make runs at 750°F after the liquid oxygen run, bearings fabricated from M-10 steel for the races and balls and stainless steel for the etainers were used. A running time of 6 hours was obtained at 750°F after an initial run in liquid oxygen. The operating temperature range for the experimental film was over 1000°F. It should be noted that a phosphate pretreatment used with the 1010 retainers could not be used for the stainless steel retainers of the high temperature bearings. A number of pretreatments for stainless steel have been investigated. The results of a screening test are shown in Table 2.

**Table 2**

**Results of Falex Endurance Tests**

Load: 500 pounds
Specimens: Pin—Stainless Steel, C-35
V-Blocks—1137 Steel, C-20

| Test Pin Pretreatment | Test Pin Coating | Running Time (Min.) to Failure |
|---|---|---|
| None | None | Less than 1 |
| None | 23A | 28 |
| Acid Etch | " | 23 |
| Sand Blast | " | 31 |
| Vapor Blast | " | 188 |
| WO-1 | " | 126 |

The pretreatments included an acid etch, sand blast, vapor blast and a commercial treatment designated WO-1 (essentially an aqueous solution of phosphoric acid). The lubricant used in all cases shown was the same ($MoS_2$—graphite—Na silicate). Test results showed the vapor blast to be the most beneficial pretreatment. The apparatus shown in Plate 6 is a Falex Lubricant Tester and was used as a screening device. The specimens consist of a test pin (fabricated from stainless steel for this investigation) and two steel V-blocks. The V-blocks were not pretreated or lubricated. The pin was the component which was pretreated and lubricated. The retainers of a number of high temperature bearings have been vapor blasted and lubricated with experimental films. 750°F tests will be conducted on recently installed high-temperature, high-speed test spindles.

Other properties of the experimental films have been investigated. The apparatus used to evaluate the starting torque characteristics is shown on Plate 7. It consists essentially of a test bearing, a bearing housing, a side load and a test shaft. The equipment is sufficiently compact that it can be placed in a sub zero cabinet and tests conducted at controlled temperatures. A comparison of results obtained on the experimental film and a MIL-G-7421 grease is shown in Table 3.

**Table 3**

**Low Temperature Torque**

Apparatus: ASTM D1478-57T

| Temperature | Lubricant | Starting Torque(g.cm.) |
|---|---|---|
| −100°F | MIL-G-7421 Grease | 4764 |
| −100°F | 23A | 472 |
| +77°F | MIL-G-7421 Grease | 177 |
| +77°F | 23A | 118 |

The MIL-G-7421 grease was designed for operation at −100°F. It can be seen that the starting torque value for this grease is approximately 10 times that of the experimental film. At 77°F the values for both materials are in the same range.

In Table 4, the high temperature stability results for a MIL-G-25013A grease, the best high temperature military grease available today, a commercial dry film and the experimental film are compared.

**Table 4**

**Film Temperature Stability**

Temperature −700°F
Specimen: Panel-4130 Steel

| Lubricant Film | Condition After Test |
|---|---|
| Grease MIL-G-25013A | 100% Evap. of Base Oil (4 Hours) |
| Bonded Film Organic Binder | Film Degraded-Easily Wiped Off (1 Hour) |
| Bonded Film Inorganic Binder | No Break Down (24 Hour Test) |

It can be seen that after 24 hours at 700°F, no breakdown of the experimental film is observed while the other two lubricants were degraded within several hours. An 800°F test was also conducted on the experimental film. No breakdown was observed after 24 hours at this temperature. Other Naval Air Material Center experimental films have been subjected to temperatures as high as 1200°F and after 24 hours at this temperature no breakdown was observed. Table 5 shows a number of component materials under investigation for high temperature lubricants. In addition to the silicate binders, phosphates and borates binders are being used.

**Table 5**

**Experimental Dry Film Components Under Investigation at NAMC**

Lubricants— $MOS_2$, BN, $PbI_2$, Pb, PbO, $WS_2$, Ag, AgI, CdO, $Ti_2S_3$, Graphite, $Ag_2SO_4$+
Binders— $NaPO_3$, $Na_2B_2O_4$, $Na_2SiO_3$, $K_2SiO_3$

In addition to high temperature studies, nuclear radiation resistance is also being investigated. A number of

*(Continued on page 33)*

# CONSIDERATIONS IN THE DEVELOPMENT OF HIGH ENERGY SOLID PROPELLANTS

By

**Dr. Evan C. Noonan**

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The opinions expressed in this document are those of the author and do not necessarily coincide with those of the Department of the Navy.

**Abstract**

It is suggested that future research in high energy solid propellant technology be directed toward chemical reactions which produce low molecular weight product gases at reasonable flame temperatures. Requirements for successful solid propellants with respect to ballistic behavior, physical properties, thermal stability and explosive sensitivity are reviewed. Suggestions are made for extending the elastomeric matrix of composite propellants without increasing their explosive sensitivity.

**Introduction**

Advantages of solid propellant rocket motors from the standpoint of simplicity and of readiness are widely recognized. Equally well known is the fact that present solid propellants cannot achieve the specific impulse, on the weight basis, provided by liquid bipropellant systems in common usage. On the basis of specific volume impulse, however, solid propellants still have a great deal of merit. In applications where the missile system is subjected to high drag forces, the gap between solid and liquid propellants is effectively decreased by reason of the higher overall density of the solid. Over the years, surprising success has attended efforts to increase the specific impulse of solid propellants. It is the purpose of this paper to point out directions which future research and development in this field should take in order to achieve delivered impulses in the neighborhood of 300 pound seconds per pound or more. Inspection of the specific impulse equation

$$I_{sp} = \sqrt{\frac{2\gamma}{g(\gamma-1)} \frac{RT_c}{M}\left[1 - \left(\frac{P_e}{P_c}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

or

$$I_{sp} = \sqrt{k\left(\frac{\gamma}{\gamma-1}\right)\left(\frac{T_c}{M}\right)\left[1 - (0.0147)^{\frac{\gamma-1}{\gamma}}\right]}$$

immediately provides the conclusion that the specific heat ratio, $\gamma$, of the gaseous products as well as their molecular weight, M, should be as low as possible while the adiabatic flame temperature, $T_c$, of the propellant should be as high as possible. (We shall restrict our consideration to the conditions under which specific impulse is ordinarily reported for solid propellants: a chamber pressure of 1000 psia and optimum expansion to 14.7 psia—to which the second equation for $I_{sp}$ applies.) At once we are faced with compromises. Gases which have a low molecular weight perforce have high values of specific heat ratios, since they invariably are gases of simple molecular structure and a limited number of degrees of freedom. In principle we are limited in flame temperatures by the energy which may be packed in chemical bonds. The cyanogen-ozone flame, for example, reaches about 5200°K or 8900°F (Ref. 1) and is near the upper limit to be expected from chemical reactions. Practically, a more stringent limitation is imposed by materials of construction. Regenerative cooling is not available for solid motor nozzles; the problem of constructing satisfactory hardware for nozzles and thrust vectoring equipment therefore is a serious one in the case of solid propellant motors. In Figure 1 the melting points of various materials are marked on a plot of specific impulse as a function of temperature for various molecular weights and reasonable associated values of $\gamma$. It is quite obvious that raising specific impulse by increasing flame temperatures results in containment problems of some magnitude. Since this is the easiest approach to high specific impulse it is the one which was tried first.

**Discussion**

It is evident from Figure 1 that the most promising area for investigation lies in the direction of low molecular weight product gases. With a gas whose average molecular weight is 10 and a value of $\gamma$ of 1.30 we have the possibility of obtaining a specific impulse of 330 lbs. force seconds/lb. mass while maintaining the

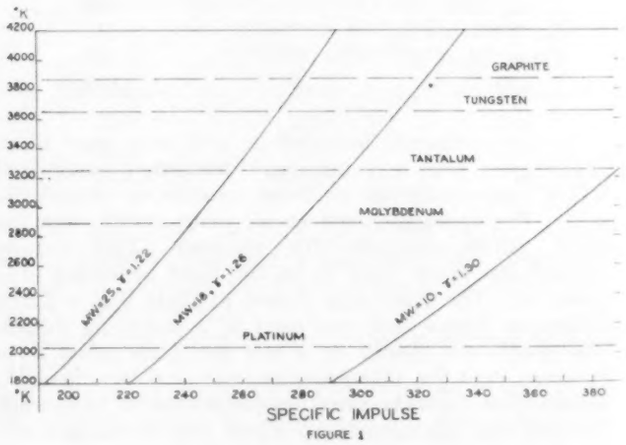


FIGURE 1

Dr. Noonan received a doctorate in Physical Chemistry from Columbia University in 1938. He joined the Navy Ordnance Laboratory in 1949, after three years as a teacher at Harvard, five years as an industrial research chemist, and three years as Associate Professor at the University of Tennessee.

Dr. Noonan is now Chief of the Physical Chemistry Division (formerly Fuels and Propellants Division) of the Naval Ordnance Laboratory, where the principal work includes ignitability and sensitivity of propellants and sensitivity of explosives.

flame temperature below 2500°K (4040°F). This is easier said than done, of course, or this area of propellant investigation would be an accomplished fact. There are very few gases between hydrogen, mol. wt. 2, and methane, ammonia and water with molecular weights of 16, 17 and 18, respectively. It is obvious that one of the major gaseous products should be hydrogen, and that, if possible, oxidants such as oxygen or fluorine should be avoided. In recent years a great deal of effort has gone into hydride chemistry. While some of the more obvious systems yielding large amounts of hydrogen have been explored, not nearly enough research has been done in this area with respect to solid propellants. Here is an excellent opportunity for the chemical industry to contribute to solid propellant technology.

It should be pointed out that condensible products do not have to be avoided in rocket propulsion. They may be a source of difficulty as far as nozzle erosion and thrust vectoring go, but they need not be deleterious from the ballistic standpoint. This allows the chemist considerable latitude in developing suitable reactions for high energy solid propellants.

**Requirements for Successful Solid Propellants**

In addition to high impulse, a number of other factors must be considered in developing a useful propellant. These are reviewed in the following paragraphs:

**Internal Ballistics**—While the development of solid propellants taxes the ingenuity of the chemist in discovering reactions which will yield high specific impulse there are a number of other restrictions which makes the task even more difficult. The vast majority of solid propellants as presently formulated have burning rates between 0.4 and 1.5 inches per second. Usually the motor designer is restricted by the missile envelope and by accelerations which can be tolerated by delicate components. If the grain is to burn radially, these requirements usually indicate use of a very low burning rate propellant; in some instances under 0.2 inch per second. If the grain is to burn cigarette-wise, then the burning rate may be required to reach 4 to 10 inches per second. In general, high energy formulations tend to be fast burning and a considerable amount of work is required to chemically modify the burning rate to achieve tolerable levels. In addition, the burning rate, at least near motor operating pressure, should be insensitive to pressure. Burning rates of propellants follow the general equation

$$r = A + BP^n$$

where r is rate of regression, P is pressure and A, B and n are constants. For explosives, the burning rate exponent, n, is apt to be near unity. For propellant usage, n should be low, around 0.1 for example, and even lower at the operating pressure of the motor. Furthermore, the effect of temperature of the propellant on its burning rate should be as small as possible, say 0.1% per degree Fahrenheit. Again considerable effort must be expended to meet burning rate requirements without sacrificing high impulse. And again it is the chemist who is called upon to circumvent the natural tendency of energetic materials to burn faster as the pressure and temperature is raised. Combustion instability, or resonance; a phenomenon where the motor pressure and combustion rate fluctuate periodically, is another problem which appears with annoying frequency. This effect is coupled with the geometry of the motor, but a chemical "fix" is often required.

**Physical Properties**—Efforts to reduce case weight, thereby increasing the burnt velocity of a motor, as well as simplification of insulation and fabrication has led to the widespread acceptance of case-bonded motors (Ref. 2). This in turn has led to rather stringent requirements for the elastic behavior of the propellant. To lessen weight the natural tendency is to use high-tensile steel or alloys for the case. As technological advances are made in the reproducibility of steel production, heat treatment and fabrication, the tendency is to reduce the safety margin between allowable load and yield. Coupled with the fact that Young's modulus for steel is nearly independent of ultimate strength, the net result is to produce a case which depends for its success upon uniform elastic deformation. Since the propellant is bonded to the case it must deform with it when the motor is pressurized. Two requirements are placed upon the propellant forthwith. First, consider a propellant grain of the radial burning type, for convenience take it as a hollow cylinder. For a case expansion of $12.96 \times 10^{-3}$ of the case diameter the following percentage increases in port perimeter of the grain would occur, assuming the propellant is incompressible.

| Volume occupied by propellant, % | Increase in port perimeter, % |
|---|---|
| 80% | 6.3 |
| 90% | 12.3 |
| 95% | 23.4 |

In the last instance, where the volume of the grain occupies 95% of the total volume, the perimeter of the port must stretch 23.4% merely to follow case expansion on pressurization. It must do so without cracking, otherwise an excessive surface area develops, the calculated ballistics are no longer applicable and the motor may blow up. Most practical propellant grains have star perforations, causing even greater strains at the valley points. The earlier literature contains many instances of heavy wall motors performing satisfactorily followed by explosions when the same propellant was cast into a thin walled case of the same size. It is not uncommon to find that elongation at maximum stress must be 40% or greater to get satisfactory motor performance. In many of the composite propellants solid loadings may reach 77%, leaving only 23% or so of elastic fuel matrix to take care of the required elongation. It is obvious that elastic matrices which furnish some of the energy requirement, instead of acting merely as a fuel, would enable the amount of elastomeric material to be increased and thereby allow better physical properties to be achieved. For reasons to be discussed later it may be unwise to make the entire propellant of high energy elastomer.

In general, the ultimate strength of the propellant is not a limiting factor, since the body forces under acceleration lead to rather low stresses. Creep in storage, however, must be controllable.

The other requirement case bonding brings has to do with curing of the elastomer. It is desirable to cure the propellant at a low temperature to prevent excessive locked-in stresses when the grain is subsequently cooled. In very large grains, it is difficult to heat the propellant from the outside and in general one must depend on mixing and casting the propellant hot, keeping the entire motor assembly hot while cure is taking place. In turn this means that there should be a low exotherm on cure.

The military often imposes extremes of temperature at which the propellant must fire satisfactorily. In addition to having good elastomeric properties at ambient temperatures, the propellant must retain these features at low temperatures. This problem alone will be recognized by the chemist as a very difficult one.

*(Continued on page 32)*

# THE MECHANISM OF THE THERMAL DECOMPOSITION OF NITROGLYCERIN IN THE LIQUID AND VAPOR PHASES

By

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## I. INTRODUCTION

IT HAS BEEN observed rather frequently that double-base (nitroglycerin-nitrocellulose, etc. mixtures) solid rocket propellants explode during storage. Qualitative investigations indicated that the cause was not due to mechanical shock nor to any unusually high temperature rise. Continued observations of this phenomenon seemed to suggest that its cause might be attributable to some sort of a chemical transformation occurring in the propellant mixture over a period of time. Obviously, such a degradation leading to detonation could conceivably be caused by any one of several, or a combination of two or more, of the components which make up the complex double-base type propellant. It was decided, however, that as a first step in attempting to elucidate this problem, a thorough study of the kinetics and mechanism of the thermal decomposition of pure nitroglycerin should be undertaken. The present research reports the results of these investigations which were supported under a contract with the U. S. Naval Propellant Plant.

Nitroglycerin has been the subject of a great deal of interest ever since its discovery about 110 years ago. Its pharmaceutical value on the one hand, and its property of exploding under mechanical and thermal shock on the other, has made this compound an intriguing subject of extensive study. The amount of effort devoted to the investigation of the chemical and physical properties of nitroglycerin is clearly indicated by the numerous articles available in the scientific literature. Most of this work, however, has centered around problems of practical significance. There is little or no agreement, for example, as to the energy of activation for its thermal decomposition; the mechanism whereby nitroglycerin decomposes into its final products has been speculated upon but no detailed study to supply experimental evidence for the proposed mechanisms has been made.

In view of the complexity of the nitroglycerin-molecule, it was felt that the information obtained by manometric studies was not sufficient to enable one to determine the exact stepwise mechanism of decomposition. Also, it was felt that the irregularities in the values of the kinetic constants observed in previous studies could not be resolved solely by observing the rate of pressure increase of reaction products. Consequently, it was decided to follow the decomposition of nitroglycerin primarily by an infrared continuous scan method. By so doing, one could follow instantaneously the rate of disappearance of nitroglycerin, the formation and disappearance of intermediate products, and the formation of the final products of decomposition.

Dr. Charles E. Waring is currently directing two rocket projects for the U. S. Navy at the University of Connecticut. His field of specialization in science is Chemical Physics, particularly in respect to solid and liquid rocket propellant systems, and combustion mechanisms of high energy fuels. Dr. Waring, during the World War II period, served as scientific advisor to the Commanding General, First Allied Airborne Army 1944-46, and has been awarded the Presidential Citation for Merit. He has a B.Sc. degree from Muskingum College, a Ph.D. in Chemistry from Ohio State University, and he also did post Ph.D. work in Chemical Physics at Oxford University.

## II. EXPERIMENTAL

**A. Material.** The nitroglycerin was prepared by the method of P. Naoum.[1] The product was dried over anhydrous calcium chloride and stored at dry ice temperature. The nitroglycerin prepared by this method had a spectrum identical to a small amount of vacuum distilled nitroglycerin.

**B. Apparatus.** In the study of the vapor phase decomposition of nitroglycerin a 220 c.c. round-bottom flask was used. Attached to the flask was an 8 mm side arm for introducing the sample, and a capillary side arm for evacuating the flask and introducing gaseous additives.

The rate of the liquid phase decomposition was studied employing a similar 59 mm flat-bottom reactor. This particular shape was chosen in order to spread the liquid sample over a large area so as to minimize self-heating effects. In all rate studies, the temperature was maintained constant to within $\pm 0.1°C$.

The rates of decomposition of nitroglycerine were determined by measuring the rate of disappearance of the nitrate groups in a Perkin-Elmer Model 21 Spectrophotometer. The absorption cell used was a 48 mm pyrex cell equipped with calcium fluoride windows. The concentration of the decomposed nitrate was determined from the intensity of the absorption peaks at 1280 and 1670 wave numbers, employing the relationship.

$$D = K_c$$

where D is the optical density, log $I_o/I$, C is the concentration of nitroglycerin in chloroform, and K is the cell constant.

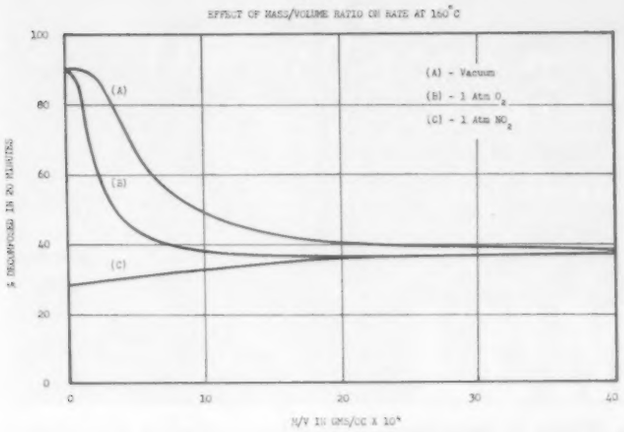
The gaseous products of decomposition at various time intervals were introduced and analysed in this same cell.

In order to continuously follow the decomposition of nitroglycerin and the stepwise appearance of products, a high temperature infrared absorption cell having calcium fluoride windows was used. The scanning speed in these studies was one micron per three minutes.

## III. RESULTS

**A. Order of Reaction.** Above 140°C, the thermal decomposition of nitroglycerin was found to be homogeneous in both the vapor and liquid phases. The rate of reaction, however, was found to be dependent upon the ratio of the mass of nitroglycerin to the volume of the reaction flask; in other words, the rate was dependent

Figure I




upon the mass/volume ratio. If one plots, for example, the rate of decomposition versus the mass/volume ratio at 160°C, Figure I is obtained. It is noted in Curve A that the rate is fairly constant over a short range up to a mass/volume ratio of $1.5\times10^{-4}$ grams/cc. On further increase of sample loading, the rate undergoes sharp decrease until a value of $15\times10^{-4}$ gms/cc is reached. Above this value the rate is independent of the mass/volume ratio.

It was established that at 150°, 155°, and 160°C and at mass/volume ratios of $0.5\times10^{-4}$, $0.7\times10^{-4}$, and $1.43\times10^{-4}$ gm/cc, respectively, nitroglycerin decomposes solely in the vapor phase. The reaction was first order and over this temperature range the rate of decomposition of nitroglycerin vapor can be expressed by

$$k=10^{15.5}\times e^{-36,000/RT}$$

Over the same temperature range and at a mass/volume ratio of $35\times10^{-4}$ gm/cc, nitroglycerin decomposes almost entirely in the liquid phase and the rate is also of the first order. There was, however, a gradual increase of this function as the reaction proceeded, suggesting an autocatalytic effect occurring in the liquid phase. To eliminate this effect, the function

$$k=2.3/t \log (a/a-x)$$

was extrapolated to the beginning of the reaction. Using these values, the rate of the liquid phase decomposition is given by

$$k=10^{20.2}\times e^{-46,900/RT}$$

The striking difference between the rate expressions for the vapor and liquid phases is immediately apparent.

The rates of decomposition of nitroglycerin were also determined at a mass/volume ratio of $2\times10^{-4}$ gm/cc at 140°, 150°, and 160°C. At this mass/volume ratio, the reaction took place predominently in the vapor phase at 160°C, about equally in the vapor and liquid phases at 150°C, and mostly in the liquid phase at 140°C. The rate expression for the mixed phase decomposition of nitroglycerin is

$$k=10^{22.4}\times e^{-49,800/RT}$$

It is noted that both the frequency factor and the activation energy for the mixed phase are measurably higher than in the vapor or liquid phases.

**B. Products of Reaction.** A careful examination of the infrared spectra recorded during the course of the decomposition of nitroglycerin at 150°C by the continuous scanning technique revealed that only nitrogen dioxide is evolved during the initial stage of the reaction. This is almost immediately followed by the appearance of formaldehyde. After a short period, the absorption peaks of carbon monoxide, carbon dioxide, and nitric oxide appear simultaneously. Traces of nitrous oxide are formed during the latter part of the reaction. These are the only compounds identified in the decomposition of nitroglycerin at 150°C and between 2 and 15 microns. At temperatures below 150°C, small amounts of formic acid were also observed. Water was also present but its exact quantitative concentration was impossible to determine.

The gaseous products of decomposition were quantitatively determined by infrared analysis at 150°, 160°, and 170°C for a mass/volume ratio of $2\times10^{-4}$ gm/cc. For each analysis, the sample was brought up to one atmosphere pressure with helium. Table I presents the results at 160°C, which are typical.

**Table I**

**Analysis of Products of Decomposition of Nitroglycerine at 160°C.**

$M/V=2\times10^{-4}$ gm/cc

**Pressure in mm. Hg at 25°C**

| Time(min.) | CO | $CO_2$ | NO | $NO_2$ | HCOOH | % N. G. decomp. |
|---|---|---|---|---|---|---|
| 2.5 | trace | trace | trace | 5.3 | — | 20 |
| 5.0 | 1.0 | 0.6 | 1.5 | 8.9 | — | 41 |
| 10.0 | 3.5 | 2.2 | 5.0 | 13.7 | trace | 66 |
| 20.0 | 8.3 | 5.2 | 14.5 | 13.7 | 0.5 | 86 |
| 30.0 | 11.9 | 7.1 | 24.0 | 9.2 | 1.5 | 92.5 |
| 40.0 | 13.5 | 8.6 | 27.5 | 9.2 | 1.0 | 97.0 |
| 50.0 | 15.5 | 9.4 | 30.0 | 6.2 | 0.2 | — |
| 60.0 | 16.5 | 9.8 | 35.5 | 3.9 | 0.2 | — |
| 300.0 | 20.5 | 12.0 | 39.5 | 0 | trace | — |

**C. Autocatalytic Effects.** It was discovered that at temperatures around 115° and 120°C, the liquid phase decomposition of nitroglycerin was autocatalytic. Additives such as helium, nitrogen, nitric oxide, and carbon dioxide do not increase the rate over that in vacuum. Oxygen and water vapor exhibit considerable accelerating effect. The effect of nitrogen dioide was pronounced. After an induction period, a considerable acceleration occurs.

The analytical results indicated that the autocatalysed decomposition of nitroglycerin is nitric acid catalysed hydrolysis of the ester. The nitric acid is formed according to

$$3NO_2+H_2O\rightleftarrows2HNO_3+NO$$

This is supported by the fact that above 140°C, the decomposition of nitroglycerin is unimolecular and, as shown in Figure I, is not catalysed by $NO_2$. At these temperatures the equilibrium is entirely on the left.

The observed catalytic effect of oxygen is due to the oxidation of NO to $NO_2$, the latter then accelerating the decomposition below 140°C.

## IV. DISCUSSION

The experimental results indicate that the thermal decomposition of nitroglycerin can occur by two mechanisms; the autocatalytic which occurs at temperatures below 140°C and is favored by a large mass/volume ratio, and the first order mechanism which proceeds at higher temperatures. The low temperature autocatalytic mechanism may be responsible for the detonations in double-base propellants since moisture would catalyse the process.

In Figure I, the effect of mass/volume ratio on the decomposition of nitroglycerin was presented. Also shown is the effect of oxygen and nitrogen dioxide. It is seen that at M/V ratios above $1.5\times10^{-4}$ gm/cc, the rate falls off rapidly while at smaller ratios it is constant. At ratios greater than $1.5\times10^{-4}$ gm/cc, the rate is essen-

tially unaffected by M/V increases. It will be recalled that at M/V ratios above $1.5\times10^{-4}$ gm/cc nitroglycerin is decomposing almost entirely in the vapor phase at 160°C. At 20% decomposition time, Table I shows that very little $NO_2$ is produced initially. As the decomposition proceeds the concentration of $NO_2$ evolved is high and hence the vapor phase is inhibited. That this is the case is shown by Curve C, Figure I. As the M/V ratios increase from the mixed to the pure liquid phase, it is observed that $NO_2$ has less and finally no apparent effect since a limiting rate is reached. The kinetic data indicate that the liquid phase rate is slower than that in the vapor. Curve C now suggests why this is so, namely, because the liquid phase is fully inhibited at all times by the $NO_2$ evolved. The degree of inhibition of the vapor phase decomposition, on the other hand, depends upon the concentration of $NO_2$.

From the kinetic and analytical data the following mechanism is proposed for the decomposition of nitroglycerin above 140°C:

1. $C_3H_5O_3(NO_2)_3 \rightleftarrows C_3H_5O_3(NO_2)_2 + NO_2$
2. $C_3H_5O_3(NO_2)_2 \rightarrow H_2CO + NO_2 + H_2CONO$ (HCO)
3. $H_2CONO_2 \rightarrow H_2CO + HCO + NO_2$ (HCO)
4. $H_2CO + NO_2 \rightarrow HCO + HNO_2$
5. $HCO + NO_2 \rightarrow HCOO + NO$
6. $HCO + NO_2 \rightarrow CO + HNO_2$
7. $HCOO + NO_2 \rightarrow CO_2 + HNO_2$
8. $2HNO_2 \rightarrow H_2O + NO + NO_2$

Step 1 in the decomposition of nitroglycerin is the rupture of the O-N bond, forming a molecule of $NO_2$ and a radical, a step common to all nitrate esters. This step is reversible, as indicated by the inhibitive effects of added $NO_2$. Since no nitrite absorption bonds have been observed in the spectrum of the decomposition products, the step

$$-CO\bullet + NO \rightarrow -C-ONO$$

is therefore excluded. This step is the predominant one in the decomposition of ethyl nitrate.

The fact that the decomposition of the nitrate groups follows a first order rate law throughout the reaction, suggests that Step 1 is the rate determining step and that all further steps involving the disintegration of nitrate groups take place at a more rapid rate. This is supported by the fact that no frequency shift of the nitrate absorption bands was observed during the course of the reaction.

Step 2 is the decomposition of the radical form in Step 1. A simultaneous bond rupture is proposed, because as in case of ethylene glycol dinitrate, it is impossible to determine whether the C-C or O-N bond is broken first. This step is further confirmed by the fact that the only decomposition product observed following the appearance of nitrogen dioxide is formaldehyde.

Step 3 represents the further degradation of the molecule. This is the least certain step and is suggested because it explains the nature and relative ratios of the reaction products, and the first order characteristics exhibited throughout the reaction.

Steps 4 through 8 represent the mechanism of the oxidation of formaldehyde with nitrogen dioxide. This mechanism was proposed by J. H. Thomas[2] and is in agreement with our experimental results. The ratio of rates of Steps 6 and 5 is assumed to be 3:2 in order to account for the observed carbon monoxide to carbon dioxide ratio.

It is noted that the radical formed in Step 3 is identical with that formed in Step 4 and is, therefore, oxidized in the same manner.

On the basis of the proposed mechanism, the over-all reaction of the decomposition of nitroglycerin vapor can be written:

$$2\ C_3H_5O_3(NO_2)_3 \rightarrow 4\ H_2CO + 2\ HCO + 6\ NO_2$$
$$2\ HCO + 1.8\ NO_2 \rightarrow 1.2\ CO + 0.8\ CO_2 + 1.8\ NO + H_2O$$
$$3\ H_2CO + 4.2\ NO_2 \rightarrow 1.6\ CO + 1.2\ CO_2 + 4.2\ NO + 3\ H_2O$$
$$2\ C_3H_5O_3(NO_2)_3 \rightarrow 3CO + 2CO_2 + 6NO + 4H_2O + H_2CO$$

Table II presents a comparison between the experimental and theoretical compositions of the gaseous decomposition products. Only the permanent gases are considered because the quantitative analysis of formaldehyde and water was not undertaken due to the difficulties involved.

**Table II**

**A Comparison of the Theoretical and Observed Composition of the Decomposition Products**

| Component | Theor. % (150°C) | Exptl. % (150°C) | Exptl. % (160°C) |
|---|---|---|---|
| CO | 27.3 | 29.0 | 28.4 |
| $CO_2$ | 18.2 | 18.4 | 16.8 |
| NO | 54.5 | 52.6 | 54.8 |
| **Amounts of Decomposition Products formed per mole of Nitroglycerin** | | | |
| CO | 1.50 | 1.60 | 1.60 |
| $CO_2$ | 1.00 | 1.02 | 0.96 |
| NO | 3.00 | 2.90 | 3.02 |
| $H_2CO$ | 0.50 | 0.38 | 0.44 |

It is seen that the experimental and theoretical composition of products are in better than fair agreement.

## V. SUMMARY

The kinetics of the thermal decomposition of nitroglycerin was studied between 140° and 160°C by following the rate of disappearance of the nitrate groups spectroscopically employing a Perkin-Elmer Model 21 Double-Beam Infrared Spectrophotometer. The values of the rate constants were determined for both the liquid and vapor phase decomposition.

It was found that the decomposition of nitroglycerin vapor follows the expression

$$k = 10^{15.5} \times e^{-36,000/RT}$$

which compares favorably with the rate expressions of the decomposition of other organic nitrates which have been studied in the vapor phase. The liquid phase decomposition rate is given by

$$k = 10^{20.2} \times e^{-46,900/RT}$$

The discrepancy between the two expressions is explained by the inhibiting effects of the nitrogen dioxide evolved, whereby the liquid phase decomposition is always fully inhibited throughout the reaction, but the degree of inhibition in the vapor phase depends upon the concentration of the evolved $NO_2$. It is suggested that this may also be the reason for the abnormally high and temperature dependent values of the fre-

*(Continued on page 32)*

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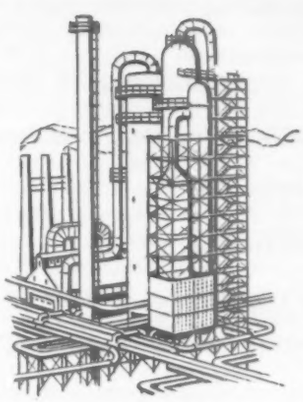

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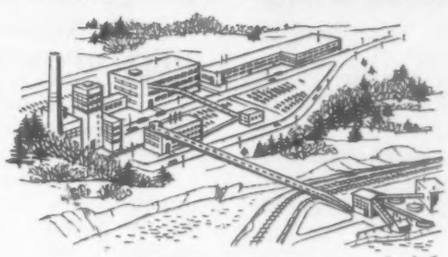

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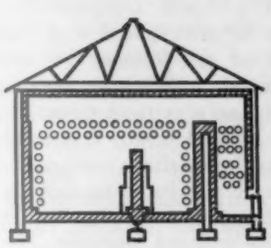

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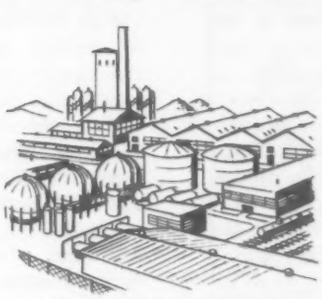

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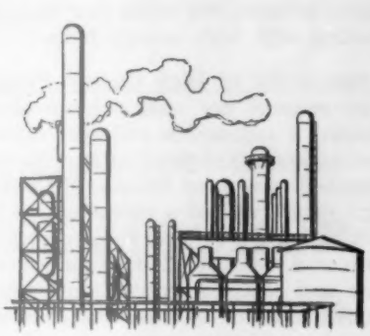

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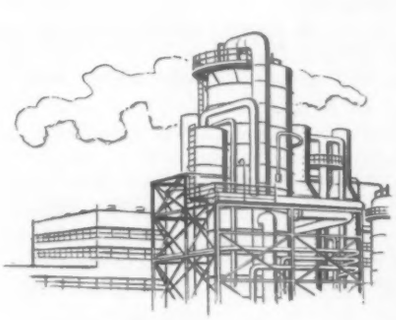

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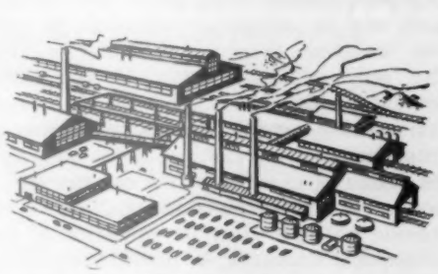

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## HIGH ENERGY SOLID PROPELLANTS

*(Continued from page 27)*

Finally, the propellant must remain an elastomer at high rates of loading, or special provisions must be made to prevent sudden pressure surges on ignition or during burning. Those experienced with the behavior of elastomers under dynamic loading, particularly at low temperatures, will recognize this also as a formidable problem.

**Thermal Stability, Self-heating and Surveillance**—Once a propellant has been cast and cured its physical properties should not change on aging. Post-cure due to unreacted groups and surface oxidation or degradation by air are common faults which the chemist is called upon to correct. The kinetics of decomposition are of course important, it is obvious that a high energy of activation must be provided in order to prevent degradation of the propellant during long term storage at high ambient temperatures. Another problem which may be anticipated with respect to very large grains is that of self-heating or spontaneous combustion. Any material which may decompose with the evolution of heat has a critical mass or configuration such that the rate of heat production exceeds the rate of heat dissipation. Under these circumstances the mass will suddenly inflame and by reason of the exponential characteristics of the governing equation it may explode or even detonate without warning. The Texas City disaster, where a ship loaded with ammonium nitrate in paper bag containers was the source of a major explosion, is an example of this sort. While present day composites are nearly immune to self-heating in grain sizes foreseeable at present, we must face this problem squarely in dealing with high energy fuels.

**Sensitivity of High Energy Propellants**—As the energy content per unit volume of a propellant is increased it approaches and even exceeds the energy content of high explosives in current use. In fact from the chemical viewpoint there is little distinction between a high explosive and a propellant. A double base propellant may burn at 0.013 meters/second; it can also detonate at a velocity of 6000 meters/second. Both double base and composite propellants appear sensitive on the impact machine test. In this instance it seems that the impact machine measures some function of the ignitability of the propellant rather than its tendency to detonate, since experience with myriads of small rockets do not reflect a detonation hazard due to rough handling. Explosive booster tests show that double base propellants can be detonated, although in general they are less sensitive than conventional military explosives. The polyurethane-perchlorate composites cannot be detonated provided they are non-porous. For some years rocket manufacturers have taken pains to de-air propellants during casting. Voids can act as stress raisers, inducing cracking; they can provide excessive surface area with subsequent ballistic effects; they can provide hot spot sites for initiation of deflagration and subsequent transition to detonation.

It is important to understand that during casting and curing precautions must be taken to prevent void formation; with high energy fuels in particular, it is essential to realize that the presence of voids can easily lead to detonation.

From our experience with solid propellants of the composite type it appears that if the elastomeric matrix is detonable by itself the finished propellant is quite sensitive. In devising energetic extenders for the elastomeric matrix it is recommended that the amount of additive be restricted to the point where the binder itself cannot support a detonation.

**Summary:**

1. The most fruitful area for research in high energy propellants appears to be in the region where low molecular weight gases are formed at reasonable flame temperatures.

2. Due to the requirement for high elongation at maximum stress for case bonded propellants, it is recommended that energetic binders be substituted for part of the oxidizer in composite propellants.

3. To avoid detonation sensitivity, the energy content of elastomeric binders used in composite propellants should be insufficient to support detonation.

4. Requirements for solid propellants with respect to ballistics, physical properties, decomposition rate and explosive sensitivity are reviewed.

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## MECHANISM OF THERMAL DECOMPOSITION

*(Continued from page 30)*

quency factor and the energy of activation as reported by previous workers[3,4].

The final products and intermediates were determined quantitatively throughout the course of the decomposition of nitroglycerin vapor. This was accomplished by cooling the reaction vessel rapidly to room temperature and examining the resultant mixture spectroscopically.

For the first time in the study of the decomposition of organic nitrates, a method was employed whereby the sample was decomposed in a thermostated infrared absorption cell, and the spectrum of the reaction mixture recorded continuously during the course of the reaction. This investigation was extended to the decomposition of ethylene glycol dinitrate, and to the oxidation of formaldehyde by $NO_2$.

On the basis of the experimental kinetic and analytical data, a complete mechanism for the vapor phase decomposition of nitroglycerin is proposed. The over-all reaction was established as

$$3\ C_3H_5O_3(NO_2)_3 \rightarrow 3\ CO + 2\ CO_2 + 6\ NO + 4\ H_2O + H_2CO$$

A brief discussion of the autocatalytic effects is also included.

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## PAINTS, PRESERVATIVES AND COATINGS

*(Continued from page 23)*

concern is that the fire point of the fluid must not be depressed nor must it be contaminated with anything that causes it to foam. The next SLIDE (20) shows storage panels used in studying these effects. One is coated with uninhibited fluid, the second with fluid to which a corrosion inhibitor has been added, and the third covered with a proprietary compatible preservative.

3. Ballast tank coatings

Landing craft (SLIDE 21) present continuing and serious problems in the preservation of sea water ballast tanks. These tanks could be sand blasted and specially coated but their large number and their rough use would make such action uneconomical. We employ oily type compounds as preservatives and apply them by flotation. Only superficial surface preparation is required. The materials do not prevent all corrosion but retard it quite effectively regardless of the condition of the surface when applied. The preservative is dumped on the water layer and as water is pumped in and out of the tank the coating adheres to the surfaces. One difficulty encountered is in determining when the tank is completely coated. Any pigment added to assist in this determination must be distinctive in color from that of the metal and yet inexpensive enough to warrant its use. Laboratory panels coated with unpigmented and colored materials of several colors are shown in SLIDE 22.

4. Strippable coatings

There have been recent advancements in both the hot and cold application strippable coatings. Improvements are still needed in the protection they offer against high humidities and temperatures. Better strippability in cold weather is needed also.

5. Woods

The preservation of wood is a problem that merits special attention. The Navy still has "iron men in wooden ships" in the fleet of non-magnetic minesweepers built during the Korean War. Ships boats are made of wood and require attention to prevent deterioration. In SLIDE 23 can be seen what happens to a 40-foot motor launch after four or five years of open storage. All our boats are now thoroughly treated with water or oil borne preservatives. Full cell pressure treatment of wood is quite effective. SLIDE 24 shows wood being loaded into treating cylinders. Dip and brush treatments are of limited value and need to be improved both as to wood penetration and effectiveness. We need a preservative to treat wooden members before lamination which will protect the wood and at the same time not interfere with adhesives used in the laminating process. Many wood preservatives are designed to be water repellant but do not make the wood vapor resistant. Water vapor causes wood to swell. Under conditions of low humidity the vapor leaves and the wood shrinks regardless of any preservative treatment. We need an economical preservative that will prevent deterioration and act to stabilize wood dimensionally.

V SUMMARY

Because ships and ship equipment are becoming more and more complex and the environments in which they must operate are increasing in severity it is mandatory that the search for better methods and materials for corrosion and deterioration prevention continue. We have described briefly our needs in selected areas as being illustrative of problems that we face. The Navy counts on the strength and breadth of the chemical industry and its research and development programs to meet our needs. Ships and ship components are just like women and if they are to remain "young" they must be painted, coated, and preserved (SLIDE 25).

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## HIGH TEMPERATURE LUBRICANTS

*(Continued from page 25)*

bearings lubricated with the Naval Air Material Center films as well as bearings lubricated with radiation resistant grease and commercial films have been exposed in the MTR to a gamma dosage of $5\times10^9$ roentgens. Results of preliminary tests show that the grease lubricants were transformed into brittle solids whereas the experimental film still provided satisfactory bearing operation.

In summary, new dry film lubricants have been developed by the Naval Air Material Center which are stable through a temperature range from minus 300°F to plus 750°F, will permit ball bearing lubrication for periods up to 240 hours and will lubricate ball bearings immersed in liquid oxygen. Based on their chemical structure, the stability in nuclear radiation and at low pressures should be satisfactory. It is anticipated that such lubricants will eliminate excess weight, increase reliability of operation and provide new mission capabilities.


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# AIR FORCE REQUIREMENTS OF THE CHEMICAL INDUSTRY

By MAJOR GENERAL M. C. DEMLER

*Director of Research and Development*
*Headquarters United States Air Force*

THE PROBLEMS which confront us in the development of superior weapon systems may often be resolved by a free discussion of ideas and information between representatives of science, industry, and the military services. It would be difficult to imagine a better opportunity for such an interchange of ideas than is provided by this meeting. We of the Air Force are most happy to present some of our requirements for your consideration.

With Explorer VI and Discoverer V sweeping successfully thru the skies, there has been a tendency in some quarters to relax a bit. However, a little thought will make it clear that our current successes are but starting points and that our orbiting paddlewheels and spheres are furnishing valuable information which must be translated into concrete requirements for future aerospace vehicles.

Coming here to present our difficulties reminded me of a little incident which happened to Hazen Miles, the Technical Director at one of our Air Force laboratories. He was making an overnight trip by rail. He had his ticket checked and was settled comfortably in his compartment. A little later there was a commotion out in the aisle and a knocking on the door. Sure enough, it was the conductor with the old story; to wit:
"There has been a mixup in reservations and you and I have a problem to solve. There is another gentleman here who also has been assigned to this space." Hazen looked the conductor right in the eye and said, "You, my friend, have the problem. I have the compartment." And he calmly closed the door.

The problems which we are talking about here today are obviously those of the Armed Services, but we are hoping that industry will keep the door open as it has in the past, and give us the needed boost toward the future. Here are some of the things which are needed:

A very definite requirement exists for new, unique and vastly improved metallic and non-metallic materials to be used for the fabrication of structures, propulsion devices (secondary power systems), and specialized components of aerospace vehicles. These substances may well be subjected to unusual natural environments and also to the very severe conditions created by passage at high speeds through the atmosphere of the earth or thru the gas envelopes surrounding our planetary neighbors. Among the natural environmental factors are high vacuum, unattenuated solar radiation, ozone, dissociated and ionized gases, meteorites and penetrating radiations such as those found by Dr. VanAllen. Induced factors include extremes of temperatures, high "G" forces, vibration, shock, weightlessness, and nuclear radiation. It is essential that great improvements be made in all classes of materials so that desired properties such as strength-to-weight-ratios, oxidation resistance, etc. will be optimized for very long periods of flight.

In directing these remarks toward requirements of the chemical industry, it is well to consider the output of that group of companies. It has been more or less customary to consider them as producers of bulk pow-

General Demler will be recalled as the Air Force officer who introduced the morning program of A.F.C.A.'s 12th Annual Meeting at Andrews Air Force Base, on May 24, 1957. He was then a Brigadier General, and was Deputy Director Research and Development, Headquarters, U. S. Air Force.

General Demler entered the military service through the R.O.T.C. Air Corps unit at New York University, where he was graduated with a Bachelor of Science degree in mechanical engineering in 1931, and commissioned in the Air Corps Reserve. He received his pilot's wings in 1932, and in 1934 attained the degree of Aeronautical Engineer at New York University and was promoted to First Lieutenant.

He was employed for four years with an aviation manufacturing company as engineer and test pilot. Subsequently ordered to active duty he became a Regular Air Corps officer on October 1, 1938. From then on he served in positions of increasing responsibility, especially in connection with scientific and engineering duties.

General Demler was one of two Air Corps officers who, in 1943, visited the secret Los Alamos Laboratories of the Manhattan Project, to obtain information as a basis for modifying B-29 aircraft for delivery of atomic bombs.

In World War II, General Demler, then Colonel, served in Okinawa with the B-29 Bombardment Wing.

General Demler's advanced education includes the degree of Master of Science in Aeronautical Engineering from University of Michigan, 1941, and the Advanced Management Program at the Harvard Graduate School of Business Administration in 1951.

General Demler was born at North Tonawanda, New York, on 23 October 1909.

ders and liquids; each company concentrating on a few items which were the raw materials for other industries. Now we find companies turning out titanium sponge; and many working in metallurgy. Structural plastics, tubing, seals, electrical insulation, etc. are produced in such variety that we might almost call the complex a "materials" or "components" industry.

These companies have been a tremendous factor in helping to develop weapon systems. A closer look at some new systems will show how some of the specific problems have been solved and will help to illustrate trends in Air Force requirements.

**(Slide 1, B-58 Hustler)**

The B-58 Hustler is our newest supersonic bomber, and it should be operational by the end of the year. As vinyl interlayers for the windshield could not withstand the high temperatures caused by aerodynamic heating, the silicone type was originated.

Most of the surface structure of the aircraft is literally glued together. The wing and vertical fin are fabricated from a bonded phenolic honeycomb core sandwich with a 2024-T 3 metal facing. For a few areas, such as elevon and engine nacelles, it was necessary to use 17-7 PH steel sandwich. Here, combinations of substances have satisfied requirements for the light weight, heat resistant and insulative structure of a supersonic bomber.

As the Air Force moves into more advanced weapon concepts, temperature problems become more critical and our dependence upon special materials becomes significantly greater. The B-70 and F-108 are expected to incorporate PH 15-7* stainless steel honeycomb structures for wing, fuselage, and control surfaces, as well as for other key airframe elements.

**(Slide 2, Dyna-Soar)**

Looking farther ahead to the Dyna-Soar, this slide shows products which meet "impossible" requirements.

You have no doubt noticed the trend from the light alloys traditionally associated with air vehicles toward the higher density, higher melting point metals. Designers have had to use structural materials three or four times the weight of aluminum and magnesium alloys. In fact, in some of the more advanced vehicles, consideration is being given to structural metals which, until recently, have only been used in hot sections of turbojet engines. This thermal trend has given birth to a new branch of materials known as "Thermal Protection Systems." Here various cooling and insulating techniques are used. Thus, there are two competing approaches . . . The "brute force" method of utilizing materials which have strength at higher temperatures and the development of various devices to protect the load bearing components. It is probable that both approaches will be required in solving the thermal problems for ballistic or boost-glide re-entry. Connected with this, of course, were the parallel requirements for higher performance solid rocket propulsion systems which have brought about a host of new thermal and associated problems.

In meeting these thermal problems, composite materials have come into their own. Under the term "composite," we are including the sandwich and the honeycomb reinforced constructions mentioned above; fiber reinforced materials, plastic and metal laminates, thermal protection systems and other similar combinations of dissimilar ingredients.

**(Slide 3, Composite Coatings)**

The beautiful layer-cake shown on this next slide illustrates a "composite" material . . . . this is an actual photograph of a laminated material. What appears to be the tray is a graphite base material. Hardly discernable is the first thin dark colored molybdenum layer deposited directly on the graphite. The light fluffy layers are aluminum oxide, $Al_2 O_3$, and the other dark layers are molybdenum metal like the first layer. The combination gives thermal insulation with some structural strength and high temperature capability.

**(Slide 4, Composite Materials)**

Composite materials offer attractive weight saving possibilities. This was an important factor in the very first aircraft and it is even more critical today. The band on the chart which indicates the composite materials shows significant improvement over the pure metal structure.

It is in the development of solid fuel rocket engines that the lid is off and most anything goes. In addition to the obvious development of propellants themselves, about which much has been written, many other problems face the chemist. For the short time, high heat flux conditions, a host of material combinations can be tried. These could provide heat sinks, ablative, sublimation and transpiration systems; and insulating systems or combinations of these types. The critical part appears to be the nozzle and here our thinking turns toward graphitic materials, improved reinforced plastics or combinations of plastics with refractory metals or ceramics.

As we peer into our crystal ball, one future trend appears certain. The organic substances which have been associated with composites are reaching their temperature limit, particularly for longer time exposure to elevated temperatures. Ceramic adhesives, inorganic laminates and ceramic core materials will replace them. Much effort will be needed to prepare and characterize the ceramics and to insure that they are properly used.

**(Slide 5, Elastomers)**

One of the most difficult chemical areas is that of compliant substances. Rubber has long been a weak point and it has taken tremendous efforts to achieve moderate gains in high temperature capabilities. Inorganic polymers offer the great hope in this area and the Air Force is particularly proud of the part its own chemists have played in the original synthesis of some of these carbonless compounds. Not too many pounds of elastomers may be used in any vehicle, but they are often essential.

**(Slide 6, Fluids and Lubricants)**

The operational capabilities which should be attained by fluids and lubricants are shown on the next slide. This depicts the operating temperatures for these substances. The steep upward slope of the curves points out the drastic changes in operating conditions which are expected and the width of each band shows a range of temperatures because of the variety of applications.

**(Slide 7, Radiation Stability)**

Efforts to improve the radiation stability of lubricants and greases must continue. That excellent progress has been made can be seen from this next slide, on which is plotted the radiation stability of specific lubricants. The attainment by 1964 of substances which can function properly after doses of $10^{12}$ ergs per gram will be a rather neat trick. A paper to be given tomorrow will expand the discussion of fluids and lubricants.

**(Slide 8, Trends in Chemical Analysis)**

A particular area of chemistry which must keep pace

*(Continued on page 38)*

* 15% Chrome, 7% Nickel, 2½% Molybdenum.

# CHEMISTRY PROBLEMS IN SPACE TRAVEL

By
DR. ALTON E. PRINCE
*Materials Laboratory*
*Wright Air Development Center*
*Air Research and Development Command*

IT CAN BE anticipated that the fundamental aspects of space age chemistry will not change much from the present or the past. The products of space age chemistry will depend, as in the past, on the ingenuity of the scientists in their laboratories. It is certain that, in time, some of the laboratories will actually be space vehicles. It seems probable that there will be less room for the extreme individualist in a corner of a laboratory by himself, because teams of people with great differences in training and experience even now are required to solve existing problems. This is true because nearly half a lifetime is required to gain training and experience to formulate sound concepts for future needs.

Another fundamental problem that can develop is that attempts will be made to place the new knowledge gained from space exploration into categories already established for our own little earth. It is believed that the exploration of the space and its contents will yield facts which do not at all fit into our preconceived, inherited and firmly established categories of the past. We and those coming along should be more than casually alert to new facts and to develop new baselines for the future. Even though the once clear lines of demarkation between the fundamental sciences are disappearing, the chemistry of materials in being and materials to come will form the basic building blocks of our future systems which will have to operate in the new environments of space. Extremes of heat, cold, vacuum and radiation include the conditions in these environments that can affect chemical properties of materials.

To illustrate what can happen in heat and a lack of air, I have a short film clip to show you. This was produced by Dr. B. W. King, of Ohio State University for the organic coatings group in the Materials Laboratory at Wright Air Development Center.

The coating is a ceramic-porcelain film on steel prepared by standard procedures. The sample was heated in air to 1600°F, then the atmosphere removed by flushing with an inert gas argon. You will note that when the air with its oxygen is removed, adhesion is lost and the coating balls up like a droplet of oil on glass. The basic chemical properties of adhesion and cohesion of coatings need far more attention than they are getting.

An example of what is considered an improved material is a glassy-bond ceramic adhesive. (1) This material, when matured at 1750°F during the hardening treatment for 17-7 pH stainless steel, gave shear strengths from 990 psi at room temperature to 980 psi at 1000°F. The highest strength recorded in these experiments was 1750 psi at 900°F. Materials derived from these appear to have qualities that will make them useful in space craft, but higher strengths at higher temperatures are needed.

Some experimentation has been done in the Materials Laboratory at Wright Air Development Center on various common materials to determine the effects of different temperatures in a vacuum. The equipment for these exposures consisted of a chamber with a vacuum capability of about $10^{-5}$ mm of mercury. The coating materials were put onto 2x3 inch clad, 2024 aluminum panels. All materials were commercial grade, without additives, except the neoprene, which was a white pigmented coating. Heat was furnished by electrical resistance and controlled by a voltage regulator. Heat was measured by a thermocouple attached to a sample panel. A 24-hour exposure was made in all cases. The exposure was started when the temperature of the control plate indicated the desired temperature. Weight loss of material after each exposure was determined.

The first slide shows the effect of different temperatures on some common materials at ambient, 200, 300, 400 and 500°F and as stated earlier in a vacuum of about $10^{-5}$mm of mercury. It will be noted that polytetrafluoro ethelene, Kel F, lost little weight up to 400°F but was almost entirely lost at 500°F. Evaluation of the neoprene coating was discontinued after the first exposure and the data show that the cellulose-acetate-butyrate, nitrocellulose and polysulfide materials were not better than could be expected under these conditions. Of the materials evaluated, only the silicone withstood these conditions entirely as shown in the second slide. An alkyd, silicone-alkyd, linseed oil and an acrylic lost considerable weight as shown.

We should look for a moment as to what happens when such a stable material as polytetrafluoro ethelene can break down. The carbon to fluorine bond is chemically very stable and probably is not the first to rupture. It has been reported (2) that the activation energy required to break down this compound is about 80K cal.

It is known that when a material of this kind degrades, first the weakest bonds are attacked (3) and this followed by breakdown at the end of a polymer chain. Very rapid degradation of the chain follows. This has been called "unzipping". In this particular material over 90% of the degradation product is the monomer $C_2F_4$ (4) (5). Very much more basic work is required looking into the causes of failure and understanding this and other degrading mechanisms so that materials can be designed to meet our new requirements.

Some organic systems seem to have properties which

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Dr. Prince, 46, is a Senior Scientist associated with the Non-Metallic Materials Division of the Materials Laboratory, Wright Air Development Center (ARDC). He is a former faculty member of Clemson College and the University of Maine.

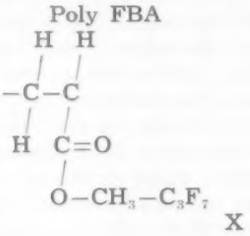
Since 1957, Dr. Prince has served as Air Force representative on the Department of Defense Coordinating Committee on Biology, and is USAF liaison member to the Division of Biology and Agriculture, National Research Council.

Dr. Prince received the B.S. and M.S. from Maine and the M.A. and Ph.D. in biology from Harvard. He is a member of the Society for Industrial Microbiology, Mycological Society of America, American Institute of Biological Sciences, American Association for the Advancement of Science, Sigma Xi, and is a Fellow of the Ohio Academy of Sciences. His papers have appeared in many technical journals.

may prove useful. For example, during investigations concerning new vinyl polymers (6) it has been shown that perfluoroaklyl propenyl ketones copolymerized with a variety of comonomers such as vinyl acetate, styrene and butadiene yielded products which varied from elastomeric in structure to powders. One series of compounds, the alkyl-hydro-perfluoroalkyl acrylates, copolymerized readily to produce rubber-like tough materials which exhibited good thermal stability.

In an attempt to improve materials a new rubber has been produced under the direction of the Materials Laboratory at Wright Air Development Center, by Minnesota Mining and Manufacturing Company. Considerable work has already been done with it. The material is Poly FBA, now known as 3M Brand Fluororubber 1F4. This is a fluoro butyl acrylate polymer with chemical structure shown in the third slide.

Poly FBA



The original properties of this material are shown in the fourth slide.

Physical Properties of Poly FBA

| Property | Value |
|---|---|
| 100% modulus, psi | 315 |
| Tensile strength, psi | 1250 |
| Elongation, % | 300 |
| Set at break, % | 9 |
| Shore hardness | 52 |

The effect of diester type fluid on common rubber materials is very severe. The effect on this same Poly FBA rubber is shown in the fifth slide.

Effect of Diester Type Fluid on Poly FBA

| Condition | Modulus (psi) | Tensile Strength (psi) | Elongation (psi) |
|---|---|---|---|
| 200 hrs at 350°F | 587 | 1060 | 186 |
| 1500 hrs at 350°F | 440 | 935 | 221 |
| 24 hrs at 500°F | 448 | 495 | 141 |

It has been found that this material can have only limited uses but it is believed that this is a direction to take in looking for new materials to meet future requirements.

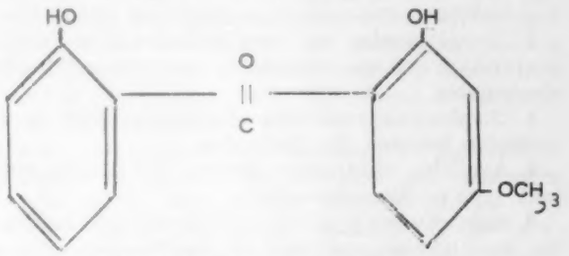
Another direction that has been taken already is with inorganic polymer systems by the polymer chemistry group in the Materials Laboratory at Wright Air Development Center. Some of these are shown in the sixth slide.

| System | Remark |
|---|---|
| -Si-O-P-<br>-Si-O-B-<br>-P-O-P- | Hydrolytic instability |
| -Al-O-Si-<br>-B-N-B- | Poor physical properties |
| -P=N-P= | No high polymers (except Cl, F and N-C-S) |

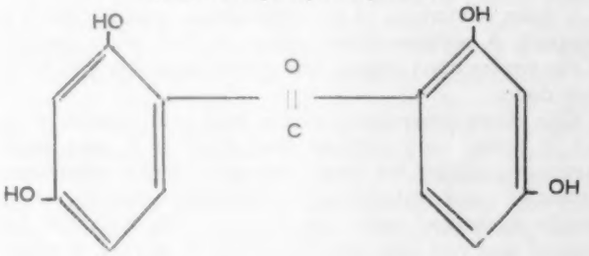
New work on B-N-B systems indicates that when methyl is added to the nitrogen and phenyl to the Boron, there is at least one compound with high temperature stability. There are many other possibilities such as -B-P-B-P- or fluoro alkyl silicones. The boron-phosphorous polymers have been made for Wright Air Development Center by American Potash Company as shown in the seventh slide. Here the $R_2$ equals alkyl side chains. Some fluoro alkyl silicone monomers are shown in the eighth slide. These are given as suggestions as to the way it is felt research should go to meet future demands. While we have the means to get off the ground, when long term space travel is initiated, it is certain that a much wider selection of materials than is presently available must be on hand.

Studies (7) have been made by American Cyanamid Company for the organic coatings group in the Materials Laboratory at Wright Air Development Center to determine the most effective ultraviolet absorbers for use in coatings for space vehicles. Of several examined for resistance to ultraviolet degradation, two of the better ones were as follows:

2, 2'-dihydroxy-4-methoxy benzophenone



2,2'4,4'-tetrahydroxy benzophenone



These compounds were among the least volatile of those examined. Ultraviolet radiation down to 2000 Å was used. These investigations showed that wave lengths below 3000 Å, or lower than any that reach the surface of the earth from the sun, are more severe degraders in the chemicals studied than the longer ultraviolet wave lengths. A very important conclusion resulting from these studies was that degradation in air was much greater than in a vacuum of $10^{-5}$ mm mercury or lower. Oxygen was believed to be the most important constituent of air to cause the greater amount of degradation.

One of the more important chemical problems in space for long range man-carrying vehicles is the production of oxygen. It is certain that you have read and heard considerable information on the subject of how plants convert carbon dioxide and water into carbohydrate and oxygen with the greatest of ease. It is possible to produce oxygen in sufficient quantities using plants. The most common kinds being considered for this job are the one-celled forms which carry on all living functions in a single body that can be measured in microns. Actually, when one tries to grow these minute plants, it doesn't take long to learn that they have all the perversities of some of the multicelled higher organisms, but they can't read and frequently won't follow directions. These small plants may be used for lack of another way on the first long range trips

into space, but there has to be a better way, a more reliable way, to produce oxygen.

The Aerospace Laboratory at Wright Air Development Center has taken a look at other methods (8) with the possibility of doing more work if available information warrants the effort. Some of the methods considered are reviewed in summary as follows:

Water Photolysis

The photolysis of water by solar energy, from information available, would be more efficient outside the atmosphere where there is more ultraviolet light. One of the more successful systems depends on the photolytic oxidation and reduction of cerous and ceric perchlorates, as photolytic catalysts, in perchloric acid solution.

Electrolysis of Water

Of the non-biological methods of producing oxygen this, at present, appears the more feasible. Results of studies indicate the following:

1. The most suited electrolytes for producing oxygen and hydrogen are sodium or potassium hydroxide.
2. Nickel anodes and iron cathodes give fairly low overvoltage and are resistant to corrosion in the alkaline electrolytes.
3. Diaphragms consisting of asbestos cloth would be desirable between the electrodes.
4. Available electrolytic systems are usually either a tank type or filter-press type.

A main advantage of the tank type would be the simple construction and ease of maintenance. The main disadvantage is the large space required.

A main advantage of the filter-press type is that it is compact. A serious disadvantage is that when one set of electrodes need repair, the whole assembly has to be shut down.

With these procedures as the best available at present, it seems very evident that there is a very large chemical problem for long time space flight operations. Extensive and intensive fundamental studies on a greatly expanded scale are desirable on both the biological and non-biological methods of oxygen production for application to space travel conditions.

A last example and one where the fields of biology, chemistry and electronics should be combined is in what has been called bioelectronics research. With the recently reported discovery of the synthesis of "Giant" protein molecules, new work for the polymer chemist is indicated. The chemical and electrical nature of the nerve cell processes should be intensively investigated so that more can be learned about the ability of these cells in the living body to search out, identify, and make decisions. With more knowledge concerning the molecular structure in the living cell, the synthesis of polymeric chains which would be responsive to an electric signal, select the necessary information and make a decision is a necessity. The ultimate purpose would be to utilize the materials developed in a device which could accomplish comparable activities. And certainly such a material would find wide use in guidance systems in vehicles for the extended exploration of space.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## AIR FORCE REQUIREMENTS OF THE CHEMICAL INDUSTRY

*(Continued from page 35)*

with or precede the others is the development of techniques for chemical analysis. On the next slide, is shown a sort of average of the improvements in the last few years and what our analytical experts believe to be reasonable requirements for the future. The sharp upward trend of the curve (even though it is plotted on a semi-logarithmic scale) indicates a real challenge.

By next year, at least one full size chemical plant should be in operation with the expectation that it will produce silicon with impurities limited to less than one part in six billion. That, of course, requires corresponding analytical accuracy.

The development of improved *non-destructive* analytical methods would be a major factor in achieving the high reliability in parts and components which is needed for reasonable assurance that a mission will not fail.

The armed services are finding it increasingly necessary to turn to *Basic* Science for the "Quantum Jumps" or significant breakthroughs which are essential to our progress. The missile designer is continually encountering areas in which the pioneering work has not been completed. For the weaponry of 1970, the scientific foundations must be constructed now.

Much more knowledge is needed about fundamental processes and properties. By a better understanding of the interrelationships of the internal structure, the binding energies, and the other atomic properties of matter, we may well provide some master plan for producing compounds with predetermined mechanical, chemical and physical characteristics. Such molecular engineering could totally revolutionize the field of materials development. Instead of spending months or years characterizing many substances in order to try to find one that will do, the chemist would synthesize what is needed.

One of our officers, Colonel Dieffenderfer, the former Chief of the Materials Laboratory at the Wright Air Development Center and now at the Industrial College of the Armed Forces, likes to tell a little story which illustrates our position. . . . . It seems that George was in the habit of taking a short cut through a cemetery on his way home at night. One day a new grave was excavated in the middle of the area and the following evening was a particularly dark one. As George was making his way along, he pitched headlong into the grave. After realizing that no bones were broken, he started trying to get out. The steep sides of the grave afforded no handholds and no matter what George tried, he just couldn't make it. He yelled and struggled but no one heard him and all efforts were in vain. So he finally just gave up and curled up in a corner. A little later, neighbor Bill came along, also feeling his way,

*(Continued on page 41)*

# CHEMISTRY OF FLUIDS FOR ADVANCED SYSTEMS AND VEHICLES

By
H. W. ADAMS and E. R. BARTHOLOMEW

*Materials Laboratory*
*Wright Air Development Center*
*Air Research and Development Command*

THROUGHOUT the history of powered flight, special purpose fluids have been as essential to vehicle performance as the structural materials used for vehicle construction. To progress from the early days of low octane gasoline and castor oil base engine lubricants, to today's modern jet fuels and extreme temperature synthetic lubricants, has required aggressive fluid research by both industrial and Department of Defense laboratories. There is little doubt that even more aggressive and imaginative fluid research will be essential to meet demands of air weapons of the future for fuels, lubricating oils, greases, hydraulic and other power transmitting fluids, heat transfer fluids, coolants and other liquid or semi-liquid materials.

Only two classes of fluids are discussed in this presentation—hydraulic fluids and gas turbine lubricants. A summary of the current state of the art in the technology of these fluids is presented, along with brief consideration of basic molecular structures now showing potential as advanced high temperature fluids for a variety of applications. This is not intended to be a comprehensive review of the entire Air Force program on fluid research, but is, instead, a brief summary of past accomplishments and current programs in two areas of considerable importance to air weapons performance.

## Hydraulic Fluids

Present operational aircraft such as the B-47, B-52, and "century series" fighter aircraft use petroleum base hydraulic fluids formulated to meet the requirements of Specification MIL-H-5606. A typical formulation would include, in addition to a light mineral oil, a lubricity additive (tricresylphosphate), a viscosity index improver (methylmethacrylate), and an antioxidant (phenylalphanaphthylamine). For a number of years, such fluids have been found suitable over the temperature range −65°F to 160°F. However, with the advent of the early supersonic fighter aircraft, a −65°F to 275°F operating range was required. It was determined that suitable performance and service life could be obtained from these same fluids over this range, but laboratory and component testing indicated that this was probably the maximum range over which dependable operation of these fluids could be assured.

Therefore, to meet the demands of higher mach number fighter and bomber aircraft, aggressive fluid research was undertaken in attempts to provide new hydraulic fluids useful over a −65°F to 400°F range. This research finally led to a disiloxane-diester blend containing a "metal deactivator", an antioxidant, and a silicone defoamer. The resulting fluid has since been described in Specification MIL-H-8446 and is currently in use in the B-58 aircraft.

Since it is anticipated that temperature requirements will continue to climb in the hydraulic and secondary power systems of future aircraft, or space vehicles during re-entry conditions, further research to improve at least the *high* temperature capability of fluids is underway. One approach being investigated at Pennsylvania State University under Air Force contract has yielded a prototype fluid for use from −40°F to 550°F ambient. As shown in Figure 1, this represents a significant increase in temperature stability over currently used fluids. The base fluid is derived by severe hydrogenation of parafinic mineral oil followed by an associated low temperature (−65° to −120°F) dewaxing process. Such prototype fluids have been pump tested and have been proved to be better than any other fluids tested under comparable conditions.

Another interesting approach to high temperature hydraulic fluids and lubricants has resulted from a study of the polyphenyl ethers. Monsanto Chemical Company and Shell Development have both performed research on these versatile fluids under Air Force contract. As hydraulic fluids, certain polyphenyl ethers show potential from +40°F to 800°F or higher, and Republic Aircraft is presently performing studies on the feasibility of using these ethers as hydraulic fluids. In addition to high temperature stability, one of the most attractive properties of polyphenyl ethers is their resistance to nuclear radiation, and intensive investigation of this behavior is now underway.

Finally, organo metallics, nitrogen containing heterocyclics, and inorganic polymeric fluids represent structures which are being investigated to determine feasibility of employing such compounds as building blocks for lubricants and hydraulic fluids. Certain of these building blocks are thermally stable in the 800°F to 1000°F range. However, modification of these structures to broaden this fluid range results in less thermally stable structures, and research is being performed in attempts to overcome this problem.

## Gas Turbine Lubricants

Figure 2 shows the temperature range capability of presently available aircraft gas turbine lubricants, additives used in these, and also certain chemical type materials which have promise for future use. It is assumed

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The speaker, Mr. Earle R. Bartholomew, 38, who presented this paper at the meeting, is the Assistant Chief, Non-Metallic Materials Division, Materials Laboratory, Wright Air Development Center (ARDC). Prior to his appointment to this position, Mr. Bartholomew was Chief, Rubber Products Section and Assistant Chief, Organic Materials Branch. He has been associated with the Center for 15 years.

Mr. Bartholomew completed his undergraduate studies in Chemical Engineering at Bucknell University and continued advanced studies at Yale University.

As head of the Southern Ohio Rubber Group of the American Chemical Society, he was the chairman of the recent High Temperature Symposium conducted by the Society. His papers have appeared in both U. S. and foreign journals.

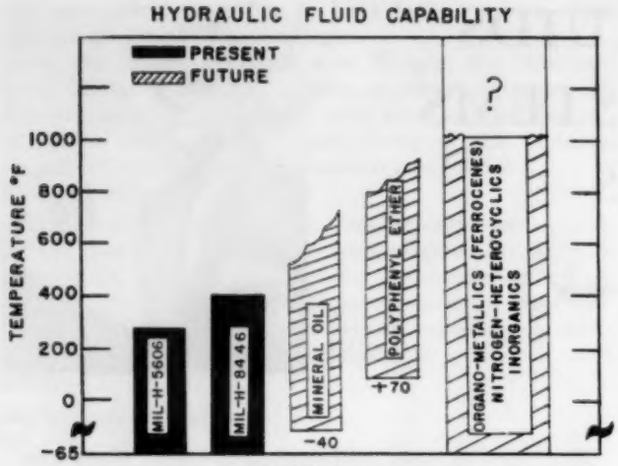


FIG. 1

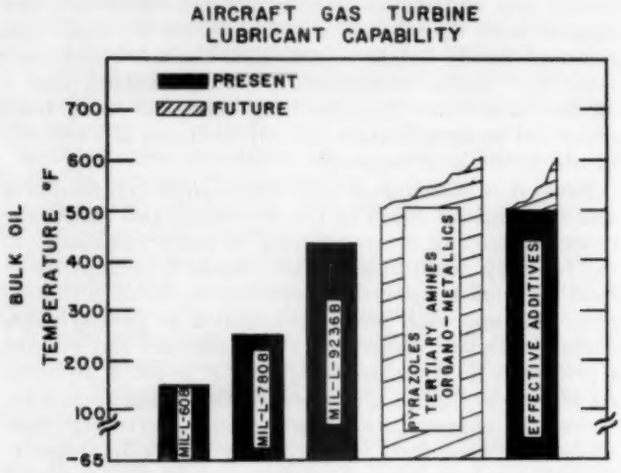


FIG. 2

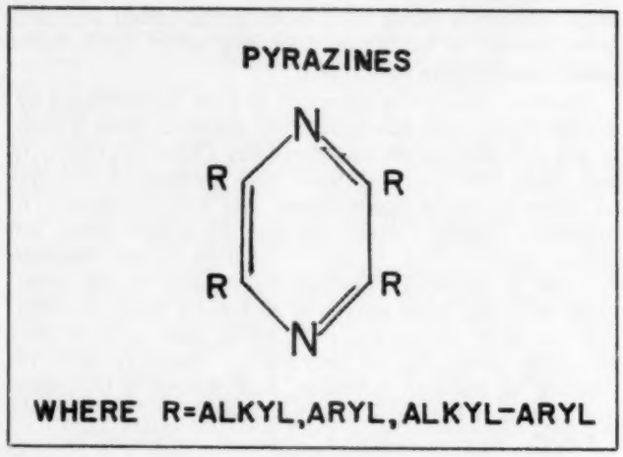


FIG. 3

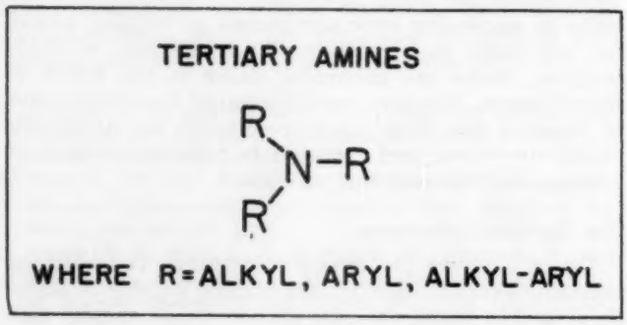


FIG. 4

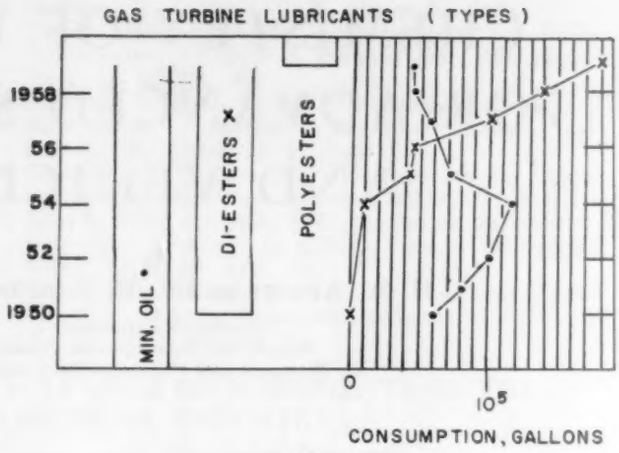


FIG. 5

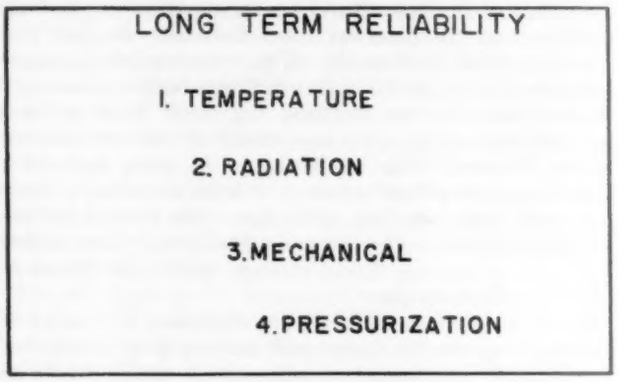


FIG. 6

here that there will be a continued need for gas turbines capable of higher thrust which will operate at higher temperatures than those of today. A petroleum based oil described by Specification MIL-L-6081 is intended for use over a range of −65° to 150°F bulk oil temperature. This lubricant remains in use today in a few current operational vehicles, including some B-47 aircraft. Fluids meeting the requirements of Specification MIL-L-7808 were introduced in 1950 and today lubricate the most powerful gas turbines used in aircraft. These fluids are synthetically derived (di-esters) and serve over the range of −65°F to 250-300°F bulk oil temperature. Such temperatures are encountered in the mach 2 speed range. Additives such as tricresylphosphate and phenothiazine are used to enhance the load carrying ability and oxidation stability of the base oil. An advanced fluid to be described in Specification MIL-L-9236B is presently being investigated and will be based upon the performance qualities of certain complex esters. Two fluids, both derived from trimethylolpropane, have been formulated and tested in gas turbines operating up to 425°F-450°F bulk oil temperature. Such temperatures could be expected in gas turbine engines operating in the mach 3 speed range. In particular, Specification MIL-L-9236B will cover formulations for use in the propulsion systems such as might be employed in the B-70 and F-108 aircraft. The main deficiency encountered in the development of these fluids has been a lack of sufficient oxidation stability which is required at the high operating temperatures. This has been recently resolved by the proper use of two new antioxidants which will be disclosed in Air Force Technical Reports and papers in the near future.

Anticipated bulk oil temperatures in even more ad-

vanced gas turbines are in the 500° to 600°F range. Propulsion systems of this type would operate in the mach 3-4 speed range and lubricants for these systems presently being investigated include pyrazines, tertiary amines, and organometallics.

Figure 3 shows the basic pyrazine ring, with an "R" denoting the points where substitution can be accomplished to derive fluids. The pyrazine ring has considerable potential as a building block for fluids requiring oxidation and thermal stability. This is based on the fact that an aromatic or heterocyclic structure containing the nitrogen atom has provided the most efficient high temperature anti-oridants and that the pyrazine ring alone shows thermal stability in the order of 1000°F.

Tertiary amines, as represented in figure 4, also appear to possess desirable characteristics for use as high temperature gas turbine lubricants. An almost unlimited number of possible compounds exist, and desirable viscometric properties can easily be obtained by proper substitution on the nitrogen atom. Pure alkyl tertiary amines have been studied and have shown excellent oxidation stability; however, it appears more desirable to derive fluids where "R" is alkyl-aryl.

Both the pyrazine ring and tertiary amine structures could be utilized in the synthesis of organo-metallics to obtain superior high temperature stability. It is believed that approaches of this type will lead to fluids suitable for meeting future lubricant requirements.

To briefly consider a matter of great importance to the chemical industry, Figure 5 shows consumption of the principal types of gas turbine lubricants during the 1950-1960 time period. It can be seen that between 1950 and 1954, the mineral oil usage continued to rise even though the synthetics were superior in capability. 1954 shows an increase in the synthetics as the Air Force and Navy converted to higher performance gas turbines. 1958 shows approximately 1.5 million gallons procured and by the end of 1959 this volume will approach approximately 2.0 millions. A projection into the future could show 3.0 million gallons of MIL-L-7808 fluid procured. If a continued need exists for higher performance aircraft gas turbines, the complex esters typified by the Specification MIL-L-9236B type polyesters could slowly replace MIL-L-7808 oils as they did the mineral oils. Peak usage of MIL-L-7808 oils by the military is estimated in 1961.

In conclusion, while discussing the future application of lubricants in advanced equipment, it would be well to point out some problems which will exist, and to present some basic means by which to cope with such problems.

Figure 6 depicts the most formidable problem in the lubrication of future aerospace vehicles. The various environmental factors such as temperature, radiation, mechanical working, system materials, pressurization and the surrounding atmosphere must all be summed to arrive at the maximum capability of the lubricant under a specific set of environmental conditions.

This summation is the "Long Term Reliability" of a specific lubricant under specified conditions. Studies are underway on all these parameters and/or combinations of them to characterize all classes of promising lubricants in terms of their maximum capabilities for various types of environmental circumstances to be encountered by both present and future aerospace vehicles.

The characterization of lubricants under specific environmental conditions in terms of long term reliability will be of benefit to design engineers with respect to choice of system materials and selection of components for the most efficient design.

It is anticipated that by the initiation of this program and with continued cooperation between manufacturers of hardware designed for aerospace vehicles, and the research and development organizations concerned with lubricants, the "State-of-the-art in lubricants" will swiftly advance to provide the needed lubricants for advanced vehicles of the future.

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## CWS HISTORY ON SALE BY A.F.C.A.

Arrangements have been made with the Government Printing Office whereby the volume of the Army official histories, "U.S. Army in World War II, The Technical Services, The Chemical Warfare Service: Organizing For War," by Dr. Leo P. Brophy and Col. George J. B. Fisher, may be procured through the Armed Forces Chemical Association. The price of this volume is $4.00.

Orders placed with the Association will be handled without delay. They should be directed to:

The Secretary-Treasurer
Armed Forces Chemical Association
Suite 408 Park Lane Building
205 Eye Street, N.W.
Washington 6, D.C.

All checks should be made payable to the Armed Forces Chemical Association.

O. E. ROBERTS, JR.
*Secretary-Treasurer*

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## AIR FORCE REQUIREMENTS

*(Continued from page 38)*

and WHAM! Down he went into the hole. He tried and tried to get out, but made no progress. George watched quietly and finally said, "Bill, there's no use trying. It is absolutely impossible for you to get out." - - - But he did. - - -

Bill met an impossible requirement by continued intensive effort, and we can solve *our* difficulties by following the same path. It will take much ***determination.***

The importance, magnitude, and scope of the Air Force materials research and development program has led us to seriously consider establishing an Air Force Materials Central. Such a Central would be the focal point of *all* materials research and development activities known to the Air Force.

Among the many functions of such a Central would be increased emphasis on new applications, information collection and dissemination, memory-type computer systems capable of digesting information of old and new developments and applying this information to the solution of new problems. Supported by a strong research and development program, this integrated Materials Central would make new materials information readily available to using agencies in industry and the services and provide a single place where requirements, programs, and technical evaluation information could be obtained.

In conclusion, I hope that this brief review of Air Force requirements has been useful to you. For those of you who wish to examine our materials development requirements in more detail, may I suggest that you inquire into the Applied Research Planning Document Release Program of the Air Research & Development Command at Andrews Air Force Base. Information on this Document Release Program is contained in the booklets which I will leave here for you to look over.

# HIGH TEMPERATURE STRUCTURAL MATERIALS

By CLAUDE W. KNIFFIN
*Air Research and Development Command*

**SUMMARY**

*This discussion concerns structural materials for aerospace vehicles subjected to an environment of 2000 to 5000 degrees F. The factors which create high temperature conditions are first considered. Data on available materials capable of enduring the heat are presented. It is concluded that few materials are fully satisfactory especially for extended periods of service. The need for increased chemical research in materials is emphasized.*

THIS IS THE aerospace age. Yesterday it was the atomic age. The day before the jet age. Today the magic word is aerospace. How far and how fast we progress in the exploration and conquest of aerospace depends largely upon the availability of materials from which to fabricate the needed aerospace vehicles.

The temperature environment in which our structural materials must perform has been and continues to be the most important material design factor. At this time period, the capability of structural materials to resist the imposed thermal flux is much more critical than the capability to withstand many other factors that are so frequently in the technical literature headlines. For example the solution of the materials problems of nuclear radiation, corrosion and erosion and the impact of meteor collision are much less severe. The temperature regime with which we are now concerned is in the order of magnitude of 2000°F to 5000°F.

The origin of these high temperatures is well known. They may result from three principal sources, aerodynamic heating, internal chemical fuel combustion or nuclear reaction and external radiation. It appears desirable to briefly indicate the order of magnitude of these heat sources as justification for the established range of temperatures just mentioned.

Aerodynamic heating of course, applies only to flight within an atmosphere. The temperatures generated are primarily functions of the air density and speed of flight. The shape and surface conditions of the vehicle are, however, of considerable importance in the intensity of heat developed. The severity of aerodynamic heating as a function of speed for 120,000 ft. conditions is shown in Figure 1.

These curves over simplify the problem. They are calculated values and were derived from equating the energy in a moving stream to the temperature rise at stagnation conditions. From the curve for real gas it may be noted that the established temperature criteria may be reached at the nominal velocity shown at the lower range of speed.

The severity of heating reached by the combustion of chemical fuels is given by Figure 2.

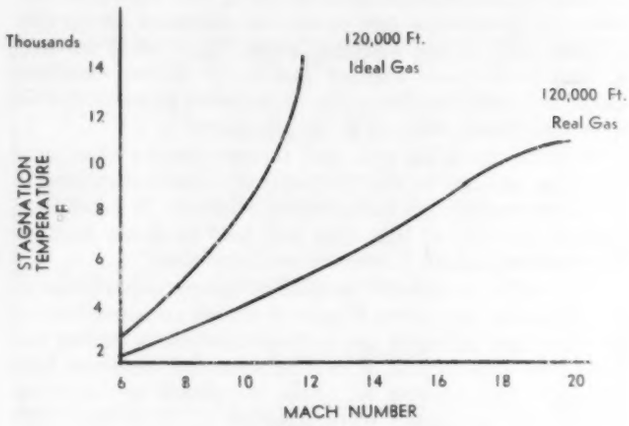


**Figure 1.**

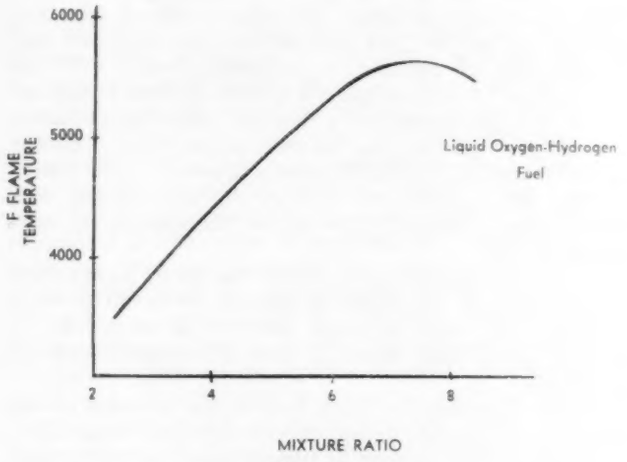


**Figure 2.**

In this case the combustion temperature was calculated by equating the heat of reaction of the fuel combination to the change in enthalpy of the product gases. In the combustion of some chemical fuels temperatures of 11,000°F are theoretically possible. The accompanying figure shows the calculated temperature for varying oxygen-hydrogen mixture ratios. Other common fuels such as oxygen-hydrazine, or nitric acid-aniline produce similiar temperature maxima not greatly at variance with the peak temperature values shown. The temperatures generated by nuclear power plants may be higher by a factor of two.

The third heat source, solar irradiation, becomes especially important for vehicles designed to operate in solar orbits. The calculated equilibrium temperature

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Mr. Kniffin is Chief of Materials Application and Technical Advisor in the Materials Division of Headquarters Air Research & Development Command at Andrews Air Force Base, Washington 25, D. C. He has occupied this position since 1954 and previously he served as Technical Director and Chief of Operations at the Climatic Projects Laboratory at Elgin Air Force Base, Florida.

Mr. Kniffin holds the degree of M.E. in Heat Power Engineering from Cornell University (1926). His previous experience has been with the Westinghouse Electric Corporation (1943-45), Baltimore Gas & Electric Company (1930-43), and York Division of Borg Warner Corporation (1926-30). He is a registered Professional Engineer and past director of the National Society and chairman of the Baltimore-Washington Section of A.S.H. & R.E.

for a black body in a circular orbit about the sun is given in Figure 3 as a function of distance from the sun. It may be noted that temperatures in excess of 2000°F may be attained for orbital distances within the realm of possibility for propulsion systems probably to be available in the near future. Vehicles without internal heat and in an earth orbit, where at least a portion of the path falls in the earth's shadow have been shown to present few obstacles for materials beyond the employment of surface reflective coating.

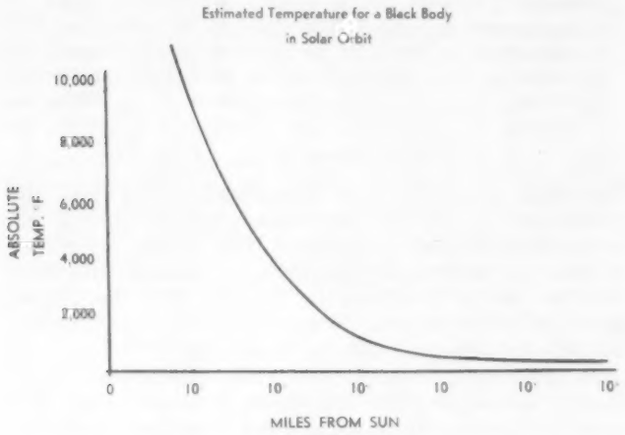


**Figure 3.**

The actual thermal environment for the structure of an aerospace vehicle may result from any combination of the preceding factors. For example, some calculations have been made for the change in temperature of an earth orbiter with and without internal heating. Figure 4 shows the results of this calculation.

Equilibrium Temperature-Spheres in Earth's Orbit

| | No Internal Heat | 10 Watts/ft² Internal Heat |
|---|---|---|
| White Paint | −180°F | −47°F |
| Polished Aluminum | +290°F | +610°F |

**Figure 4.**

With only ten watts per square foot of internal heat the temperature of a white body is raised 133° and a polished aluminum body by 320°F. This example is of course not critical as concerns the criteria selected, but does serve to illustrate the point that effective temperature levels do increase with solar irradiation and also to show the effects of variations in surface emissivity. A combination of aerodynamic heating and combustion heat such as experienced by vehicles of the X-15 type would involve temperatures within the expressed range if sustained steady state flight conditions were encountered.

Unfortunately nature has not provided man with the basic matter which will successfully meet sustained temperatures in the 2000°F to 5000°F range. Figure 5 is a plot of the melting point of chemical elements as a function of atomic number.

It is immediately apparent that the pure elements in only four ranges of atomic numbers, that is about ±5, ±25, ±45 and ±75 can be expected to withstand these temperatures for more than very limited periods. To meet the heat man must first discover and then learn to use materials with higher thermal resistance.

To satisfy this requirement materials scientists have addressed themselves principally to the development and use of five classes of materials. These have been

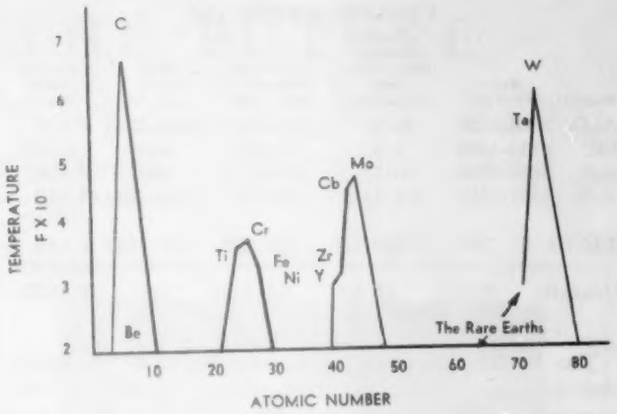


**Figure 5.**

designated as refractory metals, ceramics, super alloys, ablation materials and heat sink materials.

As will be indicated, none of these materials, which are available today, have the ability to withstand temperatures in the 2000°F to 5000°F range for extended periods. It is in this field of materials research that the chemist is in the best possible position to provide the required solution.

The term refractory metals is generally applied to both alloys and pure metals of tungsten, tantalum, molybdenum and niobium. Figure 6 represents the present state of the art for these materials as regards stress to rupture strength as a function of temperature. As may be noted these materials have useable strength at 2000°F but this property is rapidly degenerating with increasing temperature.

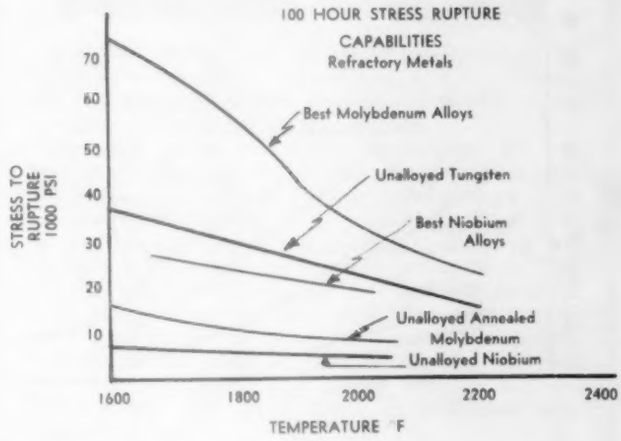


**Figure 6.**

Furthermore, all have poor resistance to oxidation at high temperature and must have surface protection to satisfy useable life requirements.

To date, research in the field of ceramic materials is far from complete. Many new chemical compounds appear to have theoretical high temperature capabilities but have as yet not been evaluated. Figure 7 represents the existing status as to maximum useful temperature and other properties of interest for those materials most available. The high performance capabilities of graphite are of utmost importance but unfortunately we lack the capability of producing this material to the requisite sizes and in the purity required. The Air Force is attempting to improve this availability problem at the earliest possible time.

A great deal of added work on all ceramics to improve thermal shock resistance and brittleness must be accomplished.

**CERAMIC MATERIALS**

| Material | Melting Point (°F) | Tensile Strength (PSI x 1000) Room Temperature | Compressive Strength (PSI x 1000) | Max. Useful Temp. °F. | Thermal Shock Resist. |
|---|---|---|---|---|---|
| $Al_2O_3$ | 3600-3700 | 25-37 | 275-400 | 2900-3300 | FAIR |
| SIC | 4700-4900 | 2-3 | 82-200 | 4000 | GOOD |
| $M_oS_{12}$ | 3600-3700 | 40-57 | 300-350 | 3000 | FAIR |
| $B_2O$ | 4550-4650 | 12.6-14.0 | 100-115 | 4000-4350 | FAIR-GOOD |
| T,C-NI | 2650 | 100-130 | 350-500 | 1500-1850 | FAIR-GOOD |
| Graphite | 6700 | 2.5-5.0 | 4.8-6.0 | 1000 | EXCEL. |

**Figure 7.**

The term superalloys is generally applied to alloys predominately consisting of chromium and nickel with varying amounts of cobalt, tungsten, molybdenum and in most cases some iron. There are approximately one hundred such alloys in general use. Figure 8 provides the relationship of 100 hour stress rupture to temperature for some of the more promising superalloys useable in aerospace vehicle structures. Most of these materials, however, have satisfactory strength for only short times at temperatures above 2000°F.

The term ablation material is applied to a type of application for material rather than to a specific material composition. The process of ablation contemplates the absorption of heat through change of state and subsequent removal of the material from the exposed surface. This change of state may result in liquification, evaporation or sublimation. Actual chemical change of a material may also occur in the ablation process.

A number of materials have been evaluated under Air Force contract by organizations such as Chicago Midway Laboratories.

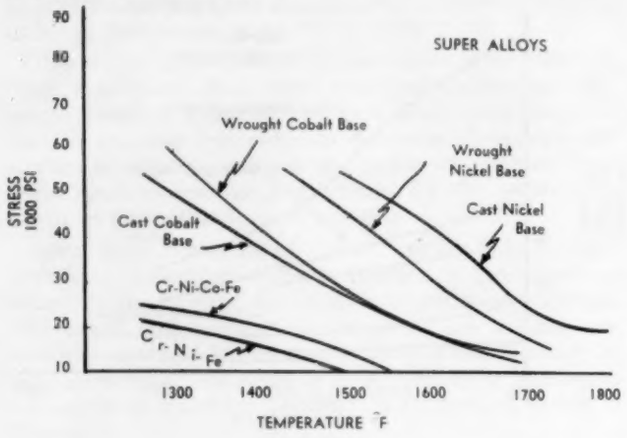


**Figure 8.**

A comparison of various materials is given in Figure 9. The relative position of carbon and copper based on quantity of material ablated under equal exposure conditions is impressive evidence in favor of carbon for this application.

The use of heat sink materials in aerospace vehicles is decreasing in importance due primarily to the weight penalty. For short periods of high temperature exposure where the material can be used at only nominal stress some applications appear, however, feasible. Figure 10 illustrates the relative comparison of eight useable materials arranged in decreasing order of specific heat.

**ABLATION MATERIALS**

| | Relative Weight Loss |
|---|---|
| Graphite | 1.0 |
| Nylon Phenolic | 1.48 |
| Silicon Carbide | 2.1-7.8 |
| Refrasil Phenolic | 2.7 |
| Glass Phenolic | 2.7 |
| Silica | 2.8 |
| Alumina | 8.5-16.9 |
| Zirconia | 15.9 |
| Copper | 74.0 |

**Figure 9.**

**HEAT-SINK MATERIALS**

| | Sp. Ht Btu/# | Melting Point °F |
|---|---|---|
| Lithium | .79 | 367 |
| Beryllium | .52 | 2340 |
| Boron | .31 | 4200 |
| Magnesium | .25 | 1202 |
| Aluminum | .22 | 1220 |
| Carbon | .17 | 6700 |
| Silicon | .16 | 2605 |
| Copper | .09 | 1981 |

**Figure 10.**

The high specific heat of beryllium coupled with the relatively high melting point makes this material of interest for heat sink applications. The former difficulties of scarcity, toxicity and fabrication problems have limited the use of beryllium in the past. For the future, however, beryllium may be expected to play an increasing role in aerospace vehicle structures.

As previously stated no available materials are completely satisfactory for the thermal environment that currently exists. The logical trend has been and will doubtless continue toward the use of composite materials such as sandwich structures and surface coatings wherein the optimum properties of specific materials are employed to meet special needs of the structure. It may be said with considerable certainty that the days for multiple use for single materials in aerospace vehicles structures are practically passed. The requirements being placed upon materials application specialists are constantly becoming more complex. A typical structure of the future may consist of first an expendable external ablative coating as the first line temperature defense, second a ceramic type material layer for thermal insulation and oxidation resistance, third a refractory metal for heat transmission and skin strength backed up by a basic titanium or steel frame. Problems of materials compatibility and equal expansion coefficients remains to be solved. One thing we are especially looking for is a compatible ablative material which can be repetitively applied to a vehicle surface by a spray process much as undercoating is now applied to an automobile.

As concerns the future needs for structural materials for flight vehicles, the Aerospace Industries Association have prepared excellent estimates of future requirements. Figure 11 is a reproduction of a chart taken

*(Continued on page 52)*

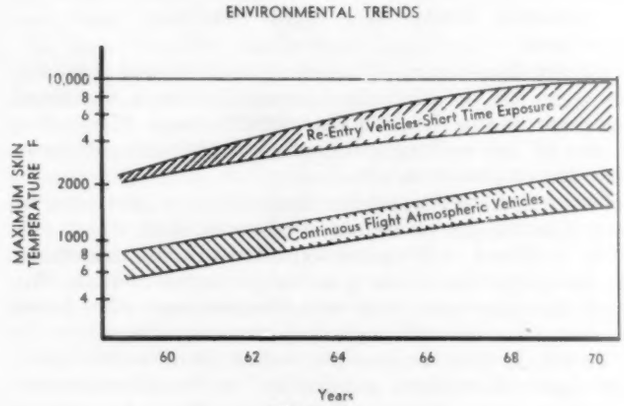


**Figure 11.**

# CATALYST FOR THE FUTURE

By

**Lieut. General Arthur G. Trudeau, USA**

*Chief of R&D, Department of The Army*

I AM GREATLY pleased over this opportunity to present to your association some of the aspects of the Army's problems today that vitally concern your association. *I predict that there is no segment of American industry that will hold as proud a place as yours when the problems of this critical period through which we are passing are viewed in the harsh light of history.*

Every link in the armor of national defense is vital but in none do we find greater strength than yours. I refer to the marvelous products that you are now able to provide. I refer to the tremendous breakthroughs and achievements to be expected shortly. I also refer, particularly, to the patriotic and selfless view taken by our great chemical industry to forego quick profits by trading in situations which would give the buyer a cheap and easy advantage in a field where their present inferiority serves as an added deterrent to war.

Before proceeding, I think we should note here the passage of the centennial honoring the oil industry. It took another 50 years to break the "oat barrier" with the automobile but now we see 75% of our energy requirements satisfied by petroleum. This contrasts to a figure of 20% only 30 years ago.

The petrochemical field is only 43 years old since Carlton Ellis found out how to make isopropyl alcohol from petroleum. Today the miracle business of producing chemicals from oil and natural gas is the fastest growing industry in the land.

In choosing my title of "Catalyst for the Future", I had all these things in mind. While it is right to hope for the dawn of peace for which our civilization yearns, we would be naive to disregard the threat that overshadows our lives. As Secretary McElroy said recently: "The military threat is as great as ever. Nothing has happened to indicate that the goals of international communism have changed."

In discussing your contributions, both present and future, I would like first to place the Army's missions in proper perspective.

The Army has four general tasks within the various levels of national security that can be foreseen. The first task is to maintain forces overseas for the deterrence of aggression or for effective initial resistance to aggression if deterrence fails. Next, the Army must maintain mobile, combat-ready, strategic forces within the continental U. S. and elsewhere for the rapid reinforcement of deployed forces or to come to the aid of allies and friends in areas where no U. S. forces are now deployed whether it be limited or general war. Third, we must provide forces as required for the defense of the western hemisphere against air attack. And finally, we must maintain an adequate basis for rapid mobilization including strong, ready, civilian components.

Within the tasks and missions of the Army, we must be prepared to fight on any future battlefield. To accomplish this under modern conditions of war, new tactical organizations have been formed and startling new weapons and materiel have been developed. We believe that the soldier himself is the most important part of any combat operation and to this end we have attempted to equip him for the severe conditions he can expect.

There is a school of thought that the ground soldier, be he Army or Marine, is no longer needed; but how to hold or recapture contested ground without them is left unanswered by proponents of this theory. Certainly

General Trudeau, who headed up the Army part of the program for this year's meeting, is well known to A.F.C.A. members; he was the banquet speaker of the meeting held in Atlantic City last year.

General Trudeau is a native of Vermont. He was born in Middlebury, July 5, 1902. He graduated from the Military Academy in 1924 and had extensive service prior to World War II in the Corps of Engineers. In 1942 he was made Chief of Staff of the Engineer Amphibian Command and later, at the request of General MacArthur, was sent to the Pacific to assist in planning amphibious operations. After returning to the United States he served as Director of Military Training of the Army Service Forces. However, this duty was interspersed with special missions to Italy, North Africa, and Great Britain in connection with invasion plans.

During the Korean War General Trudeau served as Assistant Division Commander, 1st Cavalry Division and later as Commanding General 7th Infantry Division. On his return to the United States he was made Assistant Chief of Staff for Intelligence. In 1956, promoted to Lieutenant General, he again returned to Korea as Commanding General I Corps. He was assigned to his present position as Chief of Army Research and Development on April 1, 1958.

In addition to the B.S. degree from West Point, General Trudeau has a M.S. degree in Civil Engineering from the University of California. He also has honorary degrees conferred by Seattle University and Manhattan College.

the Russians in no way subscribe to any such strategy. Let me quote to you from a recent article in an authoritative Russian military journal.

"The appearance of atomic and hydrogen weapons is considerably changing the face of war, but, of course, war cannot and will not be only an atomic-hydrogen war.

"Use of these weapons not only does not abolish the conventional armed forces but, on the contrary, leads to their augmentation.

". . . It is necessary to be oriented not toward an easy war but toward an extremely hard war which, during its entire course, will demand tremendous reinforcements for the armed forces.

"It is true that the third World War, to a much greater degree than the first or the second World Wars, will be a war of machines, a war of motors, a war of electronics, radio and radar technology, and automatic devices.

"It is true that a future war to a significant degree will be an atomic-hydrogen war, and perhaps a chemical and bacteriological one, too.

"It is true that a contemporary war is a war of the physical, chemical and biological sciences, of the technical sciences, of science in general, but it is also true that a third World War, like all past wars but to a still greater degree, will be first and foremost a war of man."

Let me give you a brief sketch of what a future battlefield may be like.

Within the battle area, to a depth of as much as a hundred miles or more, small mobile units, under a suitable command structure, of course, will be deployed at critical points and at intervals measured in miles instead of yards. Although the numerical strength per unit may be less than a battalion of World War II days, their increasing firepower already exceeds that of our old regiments. With such firepower, and obstacles, these organizations can dominate the unoccupied ground around them. When units move, they are protected against various weapon effects by armored personnel carriers. At rest, they are dug in for all-around protection and camouflaged. Highly mobile reserves are maintained for counter-attack.

For offensive operations, combat units move rapidly—both on the ground and in the air—and operate in widely dispersed formations. When necessary, units concentrate sufficiently to accomplish the mission, then quickly disperse. Aggressive, offensive action is continuous whether by fire or maneuver, or both. As in the past, tactically important terrain must be fought for and controlled; but it is selected carefully and used as a means to control the battle, destroy enemy forces, and create favorable opportunities for use of our own weapons.

Silhouetted against the horizon of this battlefield are the dark and sinister shapes of the Soviet warmaking machine. We must fully understand what its capabilities are if we are to devise sound concepts and tactics for the future as well as build effective machines of war to counter this vicious communist threat.

The eight million men in the Sino-Soviet Bloc's military forces have been organized and are maintained at a high state of combat readiness. Most of their equipment in more than 300 ground divisions is of post-war design and has been produced in enough quantity to equip their troops, maintain large mobilization stockpiles, and, in many instances, supply other Communist Bloc or satellite states. They are well and modernly equipped. In addition, all of the best Soviet scientific talent has been concentrated on the development of still more, ultra-modern weapons and technological devices at the expense of any creature comforts for their people.

I have given you this background about the Army and the military threat that we face so that you can understand more readily our programs and requirements.

The Army today receives great assistance from and enjoys a tremendous volume of business with the chemical industry. While the amount is less than in the Navy or Air Force, in the last fiscal year, we purchased a total of 84 millions of dollars worth of petroleum products. The propellants for rockets and missiles account for a substantial part of the 500 million dollars spent on these important weapons. The Chemical Corps requires a continuous product input for its 40-million dollar research and development program as do the other Army technical services.

Chemical products have been integrated into our logistics system and into our weapons and equipment programs to contribute immeasurably toward building the best peacetime Army in our history.

Today, as never before in history, there is a monumental effort to keep pace with the rapid advances in science and technology. A crisis has developed in this area between the United States and Russia because the peace of the world seems to depend on preventing Russia from gaining any substantial margin of superiority in this area. Their development of an effective, new weapons system against which we had no defense could be disastrous. In the period of tension today, this factor of time—lead time in development and production—assumes strategic importance.

Let me emphasize a vital point at this time. I firmly believe that our competition with the communists, in this part of our national program, is at present, more in the technological or engineering field than in the scientific field. There is a big difference between the two. The communists have shown that they are capable of as many scientific discoveries as we are. This should not be surprising because Russia has always done outstanding work in the scientific disciplines. For instance, some of the basic theories in mathematics and aerodynamics were developed by Russians but the nations that now comprise the Free World were first to use these theories and translate them into working machines.

The present weapons race for military superiority depends on our maintaining a superior technological know-how and using it. The ability of our industry to mass-produce hardware is a basic reason for the present commercial greatness of the United States. Certainly the chemical industry is an outstanding example of this fact. This is one of our biggest advantages over Russia. Now, as never before, we must employ this capability to the maximum extent and push it to maximum performance. Industry and labor as well as government must be unceasing in their efforts to improve procedures and utilize the full talents of all personnel.

The task of Army research and development is to develop weapon systems and materiel for a ground Army better able to fight and win and control contested land areas of the world. The program to accomplish this mission supports investigations into basic research as well as applied research and finally into the area of development—or technology. The scope is almost as broad as man's imagination can grasp because, after all, our primary interest is in man—the soldier—and what it takes to sustain him in hostile environments and gain victory.

Results of this program for peacetime use are interesting when we consider how so many past technological achievements born of military necessity have benefited our modern way of life. I refer to such things as medical discoveries, plastics, automobiles, aircraft and radios, production of the transistor and harnessing of the atom for commercial use.

As you know so well, we are vitally interested in many of the products of the chemical industry. The influence and impact of the latest advances in your field are so broad as to impinge across-the-board on our research and development efforts. As the Department of Defense budget stated: ". . . not one single modern weapons system would function without the many valuable products of the chemical industry." Here are a few examples: aluminum and stainless steel gun barrels, fiberglass and foam plastic gun stocks, artillery plastic shell casings, reinforced plastics in bazookas and other weapons, rocket and missile fuels, "free-radical" fuels that extend tank and vehicle ranges, armor and recoil system components and numerous others.

Other weapons subject to chemical contributions include a new non-metallic anti-tank mine, incendiary weapons utilizing improved pyrotechnic materials, screening smokes that have a high degree of blanketing uniformity. Explosive and ammunition type applications are, of course, entirely dependent on chemicals.

In addition, new chemical energy sources such as fuel cells promise tremendous changes in the propulsion of air and ground vehicles.

An important point you might want to bear in mind is that we must re-examine old ideas and theories that were once thought to be impractical. Many of these are being unearthed by an avalanche of scientific and technological advances and this progress may now make some of them practical. So it would be well if we dusted off some of those once-rejected ideas, and reviewed them in the light of new discoveries of today and the potentials of tomorrow.

A recent example is the revived interest in the use of chemicals as weapons. Since the First World War there has been a great lethargy toward the use of chemical weapons. This has been reflected in public attitudes and occasionally even within the armed services. The lethal and crippling chemicals stockpiled by the Armies of the world were outlawed by some nations in a limited fashion by certain conventions as you know. It is probable that these were the mutually deterrent weapons systems of World War II.

Much interest is now being shown in certain agents that are only temporarily incapacitating—agents that allow personnel to recover completely with no permanent after effects but assist in securing military objectives intact.

These chemicals are basically of two types: one is psychochemical in action and disturbs the normal behavior pattern of the individual, causing either apathy, fear, disorientation, or personality withdrawal. The other type is physically incapacitating; the enemy would be unable to fight due to temporary blindness, lowering of blood pressure, temporary paralysis or anesthetic-type action. Such agents could be used against an enemy without causing large scale destruction of cities and industries.

Chemical weapons both lethal and non-lethal, are merely another form of firepower and they would certainly add a unique capability to our arsenal. This is a field where you, here today, can give us much support. There is much to be done in research and we cannot afford to overlook any such potential when we have evidence of communist intentions and capabilities to use all forms of chemical weapons, both lethal and non-lethal.

Now what are some of the problems that confront us in the development of the kind of weapons and equipment that the future Army needs? How can industry assist the Army in meeting its objectives?

The rapidity of new inventions and breakthroughs requires a constant and studied alertness to utilize these developments. We need a constant exchange of ideas. Such information must be quickly assimilated and disseminated and a positive approach for its use adopted. To take advantage of this rapid technological pace, concurrent engineering research and production design is necessary. This is the "systems engineering" concept where production engineers enter the picture early.

To maintain qualitative superiority, *lead time* must be shortened in the face of monumental new problems, such as:

Employing new knowledge with respect to the effect of extremes of temperatures and pressures in our metallurgical research.

Developing completely new techniques in the utilization of new materials.

The necessity for precision and tolerances never before required.

Design to meet unusual and extreme environmental conditions that may be encountered.

Simplified but advanced engineering and reduced time for retooling.

Development of items with unprecedented complexities but meeting the man-machine compatibility problems resulting therefrom.

The crucial problem of early production tooling is always present to contribute toward extending our time scale. We need more capacity for rapid conversion and re-equipping of military production lines with modern machine tools and machines already stockpiled or available from consumer goods production lines.

Normal procedures are still rigid and restrictive. Acceleration of deliveries can be accomplished normally only on a crash basis involving additional changes and retrofits, the disruption of normal procurement procedures and possibly unacceptable delays. However, with some of our critical missile systems—to include propellants—planned telescoping or a high degree of overlapping in the phasing of programs is now the rule due to recognition that there had to be some relaxation in regulations to meet the emergency caused by Sputnik.

In the overall picture, I feel that an improvement in *management* and *funding procedures* in both government and industry at all levels is essential.

I have mentioned some of the requirements of industry to assist the Army in its mission. But the task for all of us goes clearly beyond this. We are faced with a national challenge that directly affects our future and probably, our survival. It is important to remember that in the field of technology we still have one of our most significant advantages over the communists. We must be more aware of this superior edge and strive not only to maintain it but to extend it. This is a test of our system compared to theirs. Next, we should emphasize our research and development programs as the basis for any future technological progress. More coordination of effort and exchange of information is needed between the Army and industry in this area.

Let us never forget for a minute the reason, the underlying cause for our tremendous military effort. We must not relax our guard nor our efforts continually to build better defense forces. Here is where a continuous catalytic action is required. This is a national task and it depends on industry, on labor, on government and on the Armed Forces—yes it depends on every loyal American. We may all have to sacrifice more to increase our readiness to meet the challenge before us; but it is better to expend our treasure than our blood. Let us do so willingly and enthusiastically for the future.

# HIGH ENERGY LIQUID PROPELLANTS: CONTAINERS AND ADDITIVES

By
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## I. INTRODUCTION

IT IS A distinct pleasure to briefly speak to you on the subject of high energy liquid propellants and associated containers and additives. Many of you represent companies or agencies which have been very helpful to the Army's missile program and I welcome the opportunity to share with you some of our experiences and problem areas.

## II. HIGH ENERGY PROPELLANTS

Before I discuss containers and additives it is probably well to give you some idea of just what I mean by "high energy liquid propellants" and some of the typical chemicals normally placed in this category.

The well established "kerosene burner" missile engine is not as low an energy system as most people may think. The principal disadvantage of the liquid oxygen/kerosene propellant combination is the cryogenic nature of the oxidizer. This combination can serve as a convenient bench mark for classifying other propellant combinations. The highest energy propellants then are considered to be those which can provide a better thrust performance than the liquid oxygen/kerosene combination. (Slide #1) The term used most frequently to compare thrust performance of various propellant combinations is the specific impulse. This is defined as the pounds of thrust obtained per pound of propellants consumed per second. The specific impulse may be likened to a factor of "energy per pound" of propellants. Most of the propellant combinations which have a greater specific impulse than the liquid oxygen/kerosene combination are selected from the chemicals shown in this slide. There is a great need for additional high energy oxidizers. Only two are currently available—liquid oxygen and liquid fluorine. High energy fuels include liquid hydrogen, hydrazine, unsymmetrical dimethylhydrazine, mixed amines, and certain boranes.

The density of a propellant is a critical factor because it will determine the dry missile tank weight. The greater the density, the smaller the tank,—and consequently the lower will be the total missile weight at burnout. Other factors being constant, it can be said that with aircraft range is a direct function of weight saving. With missiles, however, a weight saving means an exponential increase in range. Furthermore, the density of the propellant becomes more important as the size of the missile decreases. With large missiles the tank volume to area ratio is greater than with smaller missiles. Thus for small or storable missiles the combination of density and thrust performance, or density impulse value, is very important. The density impulse may be likened to a factor of "energy per gallon" of propellants. With large missiles this factor is still important, but not as critical.

Liquid hydrogen is an excellent example of these considerations. With a given oxidizer, it provides a higher theoretical thrust performance than any other known fuel. However, liquid hydrogen is probably the lowest density liquid known today. It weighs only about four pounds per cubic foot. This means that for the same mass of liquid hydrogen and kerosene fuels, the liquid hydrogen tank will have to be almost twelve times larger than the kerosene tank. Thus, even if liquid hydrogen were not cryogenic, it would be more advantageous with large missiles than with smaller or storable missiles.

(Slide #2) Most of the propellant combinations which provide the highest density impulse and may be considered storable are selected from the chemicals shown in this slide. Here we have a few more oxidizers available, as $N_2O_4$, $ClF_3$, $ClO_3F$, and FNA. However, these do not provide the thrust performance of liquid oxygen. Storable fuels include hydrazine, dimethylhydrazine, and mixed amines again, and in addition the kerosene base fuels, such as RP-1, RJ-1, or diethylcyclohexane.

Some propellants are firmly established and little additional information or R & D appears necessary. These would include liquid oxygen, RP-1, FNA, and UDMH. More information is required on the properties and handling of hydrazine, nitrogen tetroxide, and $ClF_3$. R & D programs are just now getting into high gear on liquid $H_2$ and liquid $F_2$.

## III. CONTAINERS

### A. Requirements

The composition and design of the container for propellant is naturally dependent not only upon the nature of the propellant but also upon the handling operation being considered.

(Slide #3) For shipping containers, cost and compatibility with the particular propellant are the prime considerations. For missile tanks however, the two critical factors are: compatibility and the strength characteristics at the temperature of use. The relative importance of these factors is dependent upon the particular mission for the missile.

Compatibility is considered to be no appreciable

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Mr. Riehl worked as an analytical chemist with the Louisiana State Stream Control Commission prior to entering the U. S. Army. He remained in missile work at Redstone Arsenal after his discharge from the Armed Services in 1952 and has been with the Army Ballistic Missile Agency since its establishment in 1956.

He is a member of the American Chemical Society and a Fellow of the American Institute of Chemists.

physical or chemical change in either the propellant or material for the maximum expected duration of contact. For storable propellant missile tanks the compatibility is of equal, if not more, importance as it is with shipping containers. For most space applications the propellants may be loaded into the missile up to a few hours before launch. In this case long term compatibility may be sacrificed to gain in strength properties. For example, high purity aluminum is used for shipping drums for concentrated hydrogen peroxide. However, the peroxide container in the Redstone missile is constructed of a high strength stainless steel. Although stainless steel is not suitable for long term storage of peroxide it can be used for temporary storage. In this case the greater strength to weight ratio of the particular steel employed is the over-riding consideration.

(Slide #4) The evaluation of strength characteristics is a complex task involving the metallurgical factors, such as compressive strength, tensile properties, Young's modulus, ductility, fabrication, and many others. Of course, the density is vitally important because it is the lightest weight material that will meet all structural requirements that will be the material used in the missile. Missile design, such as whether the tanks are part of the air frame or simply liquid containers will determine the relative importance of the individual metal properties. The selection of the metal is dependent also on the mission of the missile. For storable missiles, which may be subject to rough handling, a greater safety factor is necessary than in space applications. In the latter case it may be possible to provide very careful handling and thus shave off a few pounds.

B. **Materials**

The next slide lists some of the materials most commonly used for propellant containers. (Slide #5).

Generally speaking, aluminum alloys and austenitic type stainless steels are chemically compatible with missile propellants. However, other materials may be better in individual cases. Monel or nickel is preferred for contact with the halogens, as liquid $F_2$ and $ClF_3$. In all cases, laboratory tests must be made to establish compatibility with particular alloys prior to use. For example, molydenum in stainless steels apparently reacts slowly with hydrazine or $H_2O_2$. Even with propellants which can be shipped in mild steel containers, as UDMH or $N_2O_4$, aluminum or stainless steels still are used. Both of these propellants are extremely hygroscopic and increases in water content could result in severe corrosion of mild steel.

C. **Design**

The design of containers must be based on the physical properties of the propellant as well as intended service use. Cryogenic propellants require insulation by vacuum jacketing for storage other than in missile tanks. The insulation effect can be further improved by filling the evacuated space with porous materials or the new "super insulators". In general the new "super insulators" consist of many layers of multi-reflecting surfaces to reduce radiant heat transfer. These "super-insulations" are in use now in trailer trucks for cryogenic propellants. It has been reported that liquid hydrogen, with a boiling point of 20°K, or −423°F, can be shipped across country in such containers with very little evaporative loss.

"Super-insulated" containers are available thus far only in comparatively large sizes. It is still necessary to use liquid nitrogen jackets for storage of liquid hydrogen in quantities of 25 gallons or less. It is hoped that smaller "super-insulated" containers for laboratory and small test use will become available.

D. **Surface Preparation**

1. **Cleanliness**

The high order of reactivity of most propellants requires scrupulous attention to surface preparation of containers. Minute quantities of grease or foreign particles may constitute serious hazards.

The well known tendency of liquid oxygen to form shock sensitive mixtures when in contact with organic materials necessitates rigid inspection of all such containers. Not only must the LOX container be degreased exhaustively, but the drum for final rinsing solvents, such as trichloroethylene, should be carefully cleaned prior to filling at the factory. It has been found that the chemical industry usually can prepare solvents with non-volatile contents far below acceptance limits. However, as delivered, the content is occasionally higher than permissible. The majority of the non-volatile residue in trichloroethylene may well be picked up from the shipping drum.

Control of foreign particle content of containers for LOX is very important also. Small hard particles in dynamic contact with LOX and aluminum may cause detonation. This danger is not as critical as with grease impurities because the shock sensitivity with greases is generalized throughout the LOX system. With hard particles the danger is localized because it is necessary to provide a shear or impact force on the particle in such a way as to penetrate the aluminum surface. When this occurs the natural protective oxide film is removed, thus exposing bare and reactive aluminum. The resultant reaction is then between LOX and aluminum. The hard particle merely serves as a marriage broker to help bring these materials into intimate contact. Studies are being initiated to investigate these effects with other oxidizers, such as nitrogen tetroxide and liquid fluorine. It is expected that small hard particles will provide the same dangers in containers of these propellants.

2. **Passivation**

In some cases it is necessary to passivate a container prior to contact with the liquid. Fluorine containers are passivated by exposure to the gas at ambient temperature prior to contact with the liquid. This procedure is believed to provide protection by formation of insoluble metal fluorine films on the surface.

In any case it is desirable to pre-flush containers with a small quantity of the propellant prior to filling. It is realized however, that this operation may not be technically or economically feasible. In the case of liquid hydrogen containers, it is essential to pre-flush with liquid nitrogen, then hydrogen gas. The nitrogen not only conserves liquid hydrogen by pre-chilling the container, but also flushes out residual atmospheric oxygen. If the liquid hydrogen is introduced directly, unnecessary hazards will be present in both the gaseous and liquid phase. In the liquid phase, hydrogen will pick up and freeze oxygen from the atmosphere. The resulting mixture of solid oxygen in liquid hydrogen is reported to be shock sensitive.

E. **Painting & Marking**

The area of marking and identification of containers is one with which I know you are familiar. However, propellants received by the Army Ordnance Corps occasionally have been rendered unusable by the apparent lack of attention of the manufacturer to the careful selection of paints or marking. Incompatible exterior paints may introduce safety hazards or impurities in the propellant when it is poured out. For example, lead based paints could produce a flammability hazard with peroxide. UDMH is an excellent paint stripper, and will become contaminated if it is allowed to contact the exterior of most shipping containers.

I would like to suggest that more attention be focused on providing compatible paints and marking inks for shipping containers. This is not a new problem. It is merely that the highly reactive nature of missile propellants intensifies its difficulty and importance.

## IV. ADDITIVES

### 1. Blends

Additives can be used to impart more favorable chemical, physical, or support properties to a propellant. However, the same overall requirements apply to additives as to the propellant itself. Naturally, if an additive met these requirements as well, it could be used as a propellant also. Occasionally, this is the case and the final propellant is a blend of two or more. However, most additives cannot be used as propellants. Consequently it is usual that when one employs an additive to improve a certain property, there is a corresponding sacrifice with some other less important characteristic. (Slide #6) Additives currently are used in missile propellants to provide freezing point depression, corrosion inhibition, hypergolic ignition, higher thermal stability, or coloring.

Freezing point depressants are especially desirable for hydrazine and nitrogen tetroxide. Several additives are available to depress the freezing point of hydrazine, but most of these must be added in much greater concentrations than desired. Nitric oxide will depress the freezing point of nitrogen tetroxide, but increases corrosive attack on materials.

Additives for corrosion inhibition are neeeded urgently. The only propellant for which there are really satisfactory inhibitors is fuming nitric acid. Fluorides, iodides, or oxygen-iodine compounds will provide satisfactory inhibition at a concentration of approximately ½%. It may be that these additives could perform similarly in nitrogen tetroxide. This possibility should be explored.

With non-hypergolic bipropellant systems, additives may be used to induce ignition. In the Nike missile, UDMH is added to JP-4 fuel to provide hypergolic ignition with FNA. Small quantities of fluorine may be a satisfactory addition to LOX to provide a hypergolic ignition with hydrocarbon fuels. Such addition would also provide a better engine restart capability as well.

In some cases it has been found that regenerative cooling frequently caused detonation of fuels. This effect was reduced significantly by use of an additive to increase the thermal stability of the fuel.

Coloring of missile propellants is often desirable to assist in leak detection and identification in test systems. Satisfactory dyes are available for UDMH and kerosene fuels.

Two areas of promise for additives which apparently have not been seriously considered heretofore are as getters or partial catalysts.

It would be very desirable to have satisfactory additives for the gettering or scavenging of such materials as water in nitrogen tetroxide, or oxygen in liquid hydrogen.

Partial catalyst systems need investigation. The approach here would be to use a primary catalyst in the normal manner, and a "primer" or "starting" compound as an additive in the liquid propellant. The additive should be stable under ordinary conditions, but upon contact with the catalyst bed, would provide the initial starting energy. Such additives would be particularly desirable to improve cold start and decomposition characteristics of hydrazine and UDMH. Restart capabilities of auxiliary power systems based on these propellants thereby could be improved greatly.

## V. CONCLUSION

Most of the information that I have presented here has been obtained through research and development not only in government and missile industry laboratories, but also from close cooperation with laboratories in the chemical industry.

I would like to express appreciation for your continued interest and participation in this field. Thank you very much.

Slide #1

**Typical High Energy Propellants**
**Current Highest Energy Class—(Highest Specific Impulse)**

| Oxidizers | Fuels |
|---|---|
| $F_2$ | $H_2$ |
| $O_2$ | $N_2H_4$ |
| | UDMH |
| | Mixed Amines |
| | Boranes |

Slide #2

**Typical High Energy Storable Propellants**
**(High Density Impulse)**

| Oxidizers | Fuels |
|---|---|
| $N_2O_4$ | $N_2H_4$ |
| $ClF_3$ | UDMH |
| $ClO_3F$ | Mixed Amines |
| FNA | Kerosene Base |
| | (RP-1, RJ-1) |
| | Diethylcyclohexane |

Slide #3

**Criteria for Selection of Materials for Propellant Containers**

For Shipping Containers
—Compatibility
—Cost
For Missile Tanks
—Compatibility
—Strength Characteristics

Slide #4

**Evaluation of Strength Characteristic**

A. Metallurgical Properties
B. Density
C. Missile Design
D. Missile Mission

Slide #5

**Composition of Typical Propellant Containers**

| Propellant | For Long Time Storage | For Missile Use |
|---|---|---|
| Liquid $O_2$ | Aluminum, Stainless Steel | Aluminum, Stainless Steel |
| Liquid $F_2$ | Monel, Nickel | Monel, Nickel Stainless Steel |
| Liquid $H_2$ | Monel Stainless Steel | Aluminum, Stainless Steel |
| $N_2H_4$ | Aluminum, Stainless Steel | Aluminum, Stainless Steel |
| UDMH | Mild Steel | Aluminum, Stainless Steel |
| $ClF_3$ | Monel, Nickel | Monel, Nickel Stainless Steel |
| $H_2O_2$ | 1100 Aluminum | Aluminum, Stainless Steel |
| FNA | Aluminum, Stainless Steel | Aluminum, Stainless Steel |
| $N_2O_4$ | Mild Steel | Aluminum, Stainless Steel |
| Kerosene Base Fuels | Mild Steel | Aluminum, Stainless Steel |

*(Continued on page 60)*

# DIELECTRIC MATERIALS IN OUTER SPACE

By

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## Introduction

THE materiel of the Military is becoming increasingly dependent on various forms of robot brains, senses and controls because the speed and complexity of the coordination between various segments of modern weapons systems now required, transcends the capabilities of human control. Needless to say, the heart of equipment performing such tasks is electronic or electrical in nature and dielectric materials necessarily play a fundamental role in such equipment.

Until fairly recently however, research and development workers in the dielectrics field have been preoccupied only with terrestrial conditions. The recent advent of earth satellites and space probes and the use of such vehicles for communication purposes has greatly broadened the range of conditions under which electronic equipment must operate reliably and has introduced materials problems never before encountered.

It is therefore my purpose today to discuss some of the conditions to which electronic equipment are subjected during the placing of a space vehicle in orbit. A convenient way to accomplish this is to follow the equipment step by step through the various strata of the upper atmosphere and to discuss the unusual conditions affecting the performance of dielectric materials in each region.

Even before reaching extreme altitudes unusual conditions are encountered. High fuel efficiency demands that the greatest possible acceleration be maintained from the time of launching to the time when the vehicle is finally in orbit at which time all forces will counterbalance almost completely— even the normal force of the earth's gravitational field. This will place a requirement of high strength and good mechanical design on all electronic gear so that failure will not occur during this initial period of high stress before burnout of the last stage.

In addition to the high static stresses, it can be expected that large dynamic stresses will be encountered resulting from the sonic energy transmitted through the airframe of the vehicle and through the atmosphere at the lower altitudes.

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Mr. Terhune directs research on inorganic dielectric materials at the U. S. Army Signal Research and Development Laboratory at Fort Monmouth, New Jersey. He has a Bachelor of Science degree in Physics from New York University. In 1940 and 1941 he was employed as a development engineer in the field of electrochemical devices and acoustical transducers. During World War II, he served as an Officer in the Signal Corps in the development of radar and Loran systems. During his military service, he also taught physics, chemical physics, thermodynamics and statistical mechanics at the University of Florence in Italy. Mr. Terhune has been in charge of the Army diaelectrics program since 1952. His principal work during this time has been concerned with ferroelectrics in relation to their crystal chemistry, crystal physics and control of their properties by appropriate modification of their crystal lattices by cation and anion replacements.

Such problems are already well known and have received much attention during the last decade and a half.

## Stratosphere

By the time this region is reached, the vehicle has attained a sufficiently high velocity to produce extreme heating of the skin and unless adequate precautions are taken, insulation will crack, distort, or lose its electrical properties due to pyrolysis. Rapid changes of pressure with changes of altitude will also stress hermetically sealed or inadequately vented inclosures.

## Chemosphere

By the time the stratopause has been reached, pressures are so low (about 1 millibar) that further changes of pressure are inconsequential with regard to mechanical effects. The heat conductivity of the residual atmosphere is beginning to drop rapidly so that radiation rather than conductivity soon becomes the dominant factor controlling the temperature. The chemical nature of the air however begins to assume importance because of the presence of components of the solar radiation which are normally filtered out at the earth's surface.

Intense ultra violet radiation breaks down the oxygen and nitrogen into the atomic form. Ozone and ions are also produced. These react freely with many of the synthetic organics and may quickly degrade the surfaces to the point where their value as dielectrics is greatly compromised. There is little experience concerning what happens electrically when monatomic gases are adsorbed on surfaces but there is every reason to believe that the insulating properties of the surface of any dielectric will be altered adversely and that the surface will likely become the seat of violent recombination reactions.

It is also in the lower reaches of chemosphere that the electrical breakdown strength of the gases is at a minimum and throughout this whole region anomalous breakdown phenomena occur depending on the mean free path of the atoms or molecules. Such breakdowns, although they may not degrade the insulation, could be disruptive to operating equipment. Because of these disruptive effects, electronic equipment is not activated until the vehicle is in orbit or until it reaches outer space conditions.

## Ionosphere

Above the chemosphere and overlapping it slightly is the ionosphere where the pressures range from $10^{-2}$ millibars to $10^{-8}$ millibars. At the lower edge there is enough ionized gas present to permit significant currents to flow over extraneous paths which could in many instances result in serious malfunctioning of

some of the circuitry. Near the top of the region, such currents are of such low order as to have little effect on electronic gear. Temperatures, if they have any real meaning in this case, increase to high values but here the viscosity and the thermal conductivity of the gases is so low that the temperature of the vehicle is governed principally by the amount of energy radiated or received from the sun and/or the earth.

**Exosphere**

Beyond the ionosphere is the exosphere where for all intents and purposes the conditions (with few exceptions) correspond to those of that part of outer space in the vicinity of the earth's orbit. When the vehicle reaches this region, burnout of the last stage occurs and no forces act within the structure since it is in dynamic equilibrium with the earth's gravitational field.

In this region are many factors which could affect the performance of dielectric materials immediately or over a period of time. Characteristic of this area in space are primary cosmic rays, electrons, protons, the sum total of everything in the solar radiation from the infrared to soft X-rays, micrometeorites, and a vacuum, equal to or better than anything which can be produced in the laboratory. Near the earth are the Van Allen belts, a region where electrons and protons bombarding the material of the satellite produce a high intensity of X-radiation having a wide range of energies, which in time will damage nearly any unprotected dielectric beyond usefulness. It is also in this region that a satellite will spend its useful life. On the other hand, an interplanetary rocket or vehicle will have only a brief encounter with the Van Allen belts.

The primary cosmic rays are not considered to be any great cause for concern since their intensity (count level) is only about seven times greater than at sea level. Emanations from the sun however contain factors which can be very damaging such as the far ultra violet radiation. Although easily stopped by relatively little shielding such radiation can rapidly deteriorate many of the more useful dielectric materials because of the high intensities encountered. The micrometeorites present are known to be energetic enough to vaporize when they hit solid material. The surface of an insulator would no doubt be seriously degraded and probably changed profoundly in chemical constitution both as a result of the intrusion of the "space dust" and because of the chemical reactions attendant on local high temperatures produced by the impact. Small meteorites will undoubtedly cause mechanical damage to the more inadequately protected components.

The exosphere has been said to represent a high vacuum of unlimited pumping capacity. In such an environment, chemical attack by water vapor, oxygen or other active gases is non-existent.

By the same token, the surface effects of adsorbed matter on semiconductive devices are eliminated as a problem and conceivably hermetically sealed electron tube envelopes could be dispensed with to advantage.

Generally, a high vacuum can, however, affect materials adversely in two ways. The evaporation of matter is greatly enhanced by the absence of atmosphere and ablation of the material or a change in its composition due to the loss of a more volatile component may become serious in a relatively short period. Other effects will be caused by the loss or partial loss of the layer of adsorbed gases always present on matter under the more normal conditions. Subtile but important changes of appreciable magnitude are known to occur under such conditions. Little information is available on either of these effects and extensive characterization of the material of future space technology will be needed.

**Conclusions**

The various agencies directly concerned with the missile and satellite programs are well aware of the new problems in the materials area which have arisen as a result of explorations into outer space. They have initiated several general investigations to study the behavior of available materials.

The Signal Corps is supporting a modest program at the Johns Hopkins University to determine what problems will arise and which dielectrics are most suitable for use under the conditions described above.

It is most important that the tempo of these activities be increased if we are to keep pace with the advances being made elsewhere in space technology. It is almost certain that there are suitable materials on hand to meet the foreseeable needs but all our available materials require extensive additional characterization to determine which will perform most effectively.

Where it is determined that improved or special dielectrics are needed, work cannot be started at too early a date because experience has shown that even with a vigorous and persistent effort, several years are always required to introduce a major improvement in a dielectric material.

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## HIGH TEMPERATURE STRUCTURAL MATERIALS

*(Continued from page 44)*

from the "1959 Annual Forecast of Trends and Requirements" distributed by this Association. It may be noted that for the 1970 time period short term exposure to temperatures from 5000°F to 10,000°F may be expected.

If these performance requirements are to be met, progress must be made in two simultaneous yet slightly divergent directions. First, Basic and Applied Research in materials must be extended to provide new materials having improved properties. Second, the data which is currently available on materials properties must be collected, evaluated and disseminated so that more effective application can be made. As previous speakers have indicated the Air Force is attempting to accomplish both objectives. The maximum cooperation from you who are working in the important field of Chemistry is however most urgently needed.

The Air Force is especially in need of three types of materials if the planned objectives in aerospace are to be achieved. These are (a) inorganic polymers to be used principally as high temperature adhesives (b) ductile ceramics for surface coatings as well as direct structural members and (c) high purity metallic and non-metallic elements useable for many purposes including nuclear applications and electronics. This is the challenge that faces the materials chemist today.

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2. *Annual Forecast of Trends and Requirements* (1959) Aerospace Industries Association, Los Angeles 36, California.
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## BANQUET SPEECH

*(Continued from page 13)*

which lead to the glow of the night sky and to auroreal phenomena. Then there is the interaction between the upper atmosphere and the bodies of the space vehicles themselves. As various bodies reenter at high velocities they not only have high drag but they produce a strange variety of chemical reaction in the air immediately adjacent to the reentering body, but high temperatures are created and the material of the reentering body itself may melt and evaporate and participate in these chemical reactions. Furthermore at very high temperatures it is possible to create a plasma with highly active electrons and ions which serve to further complicate the chemical interaction to the point where various types of radiant energy are emitted from the heated gas layers. All of this of course is of great interest to us because these phenomena are the ones we observe when we see an enemy ballistic missile reentering the atmosphere above the target. These are the phenomena that we watch with our sensors and radars to tell that an attack is being made and these phenomena then can trigger the action from a ballistic missile defense system.

When and if we land a vehicle on the moon, then a host of interesting new chemical problems will confront us involving the raw materials that we can find on the moon. The thinking here has included a remotely controlled experiment which can be put into an unmanned vehicle and which will automatically analyze the composition of the moon's surface and transform the results of the chemical analysis into signals which then can be radioed back to the earth. A more sophisticated approach can be found in a chemical manufacturing plant which by using solar or nuclear energy transforms some of the oxides (if they exist) of the surface of the moon and extracts the oxygen and liquifies it so that it is available for breathing and for propellants for the return journey to earth. While we are, of course, not seriously concerned with these moon problems today, it is a stimulating mental exercise to speculate about such a remotely operated, transportable chemical plant.

The Department of Defense is interested in materials capable of withstanding very high temperatures. I have already mentioned the re-entry problem but similar problems exist in rocket engines, and nuclear power devices. Nuclear reactors operating at high temperatures have been found theoretically to be the most efficient for use in thermodynamic cycles with a working fluid driving a turbine which in turn drives an electric generator. For these heat generation purposes it is necessary to drive the working fluid through the reactor at temperatures in excess of 4000°F and, hopefully, eventually at 6000° F. There are no known materials to withstand these high temperatures and there is serious doubt if even future materials will satisfactorily withstand the erosion, corrosion and the nuclear radiation problems at this temperature for a long period of time. At the present time, power reactors have not been developed to operate with fluids above 2000°F. Much of the difficulty lies in the nuclear fuel element. Aside from remaining strong and stable at the elevated temperatures, the material must cope with the presence of the continuously evolving fission gases. Pockets of these gases can serve to destroy the fuel element. Compounds must be integrated with the nuclear fuel which will either absorb these gases or allow diffusion to the outside without bubble formation.

Because eighty to ninety percent of the heat in a high-power thermal power cycle must be dissipated by radiation only and therefore at high temperature (in order to keep radiator surface areas small), the radiator surfaces must be treated to possess a high emissivity. We need chemicals which will retain this property at high temperatures (as high as 1500°F) while in the high vacuums found in space.

We want to find a metal that could be built into thin sheets for the chamber and nozzles of the rocket engine and that would not have to be cooled. It would have to withstand high velocity gases at 5500°F. Unfortunately most metals will not take this high combustion temperature or erosive and corrosive action of the high speed gases. We have learned to make some ceramics or pseudo-ceramics such as silicon carbides that will withstand relatively high temperatures but they have to be built in heavy sections in order to withstand the thermal shock and in order to give a sufficient depth for a thermal gradient. They are too heavy for many applications and therefore not as good in liquid rocket engine as a liquid propellant cooled jacket. One process that looks hopeful is to use a plasma jet for depositing coatings. This method may eventually give coatings that are capable of standing up to 5000°F of temperature. Again in all of these areas we need some bright new ideas.

Together with the military services ARPA has sponsored for over a year a program on high energy solid propellant chemistry. The object here is to find a way to improve and increase the specific impulse of solid propellants from 10 to 20% over that in current use. This increase is sufficient to double the payload for such missiles as the POLARIS or the MINUTEMAN. The approaches here are to use more energetic oxidizers such as compounds of fluorine, metallic compounds which are capable of packing a large fraction of hydrogen into their molecules and the use of lightweight metals such as beryllium, magnesium, aluminum or boron. A good part of our program involves the synthesis of new chemical substances involving either an oxidizer or a fuel or sometimes a combination of both. In all our efforts we wish to obtain this high specific impulse without appreciably sacrificing the good physical properties or the good chemical stability in storage. ARPA has through the three military services some 54 contracts in being to devise these solid propellants and perform supporting research needed in order to use them effectively. We have invested some 17 million dollars last year and another 17 million this year in this project. We feel that all sorts of missile and space vehicle projects will greatly benefit by this improvement in solid rocket propellants.

I have given to you a number of examples of how progress in chemistry and chemical engineering has helped or can help various specific military devices and weapons. I could have named many more challenging problems which would be additional examples of how chemical research has aided military weapon development. In almost any military weapons system you can soon point your finger to one or two chemical or material problems which limits the performance or the growth of this device. We have long since recognized that progress in these fields can only be achieved by supporting a long range basic research program that will give us the keys to new knowledge which eventually will help us make better weapons systems. Accordingly, we are very interested in stimulating basic research and perhaps more so, the development of people capable of doing orinigal basic research. In

order to strengthen the basic research in materials, the Government has recently decided to support the establishment of a number of materials research laboratories in universities. These laboratories are intended to be of the interdisciplinary type; i.e., they will bring together the various pertinent scientific and engineering disciplines. Examples of some of the basic research activities in materials which could be fostered by such an interdisciplinary approach are as follows: (1) phenomena related to high temperature behavior of systems involving gases, (2) energy conversion as related to materials, (3) extreme temperature properties of solids, (4) basic properties of fibers and films, (5) failure producing phenomena, (6) fundamental surface phenomena, (7) structure of solids, (8) methods of synthesis of new materials, (9) theory of the behavior of materials, (10) interaction of radiation and matter, (11) effects of trace impurities, (12) basic research on extractive and processed metallurgy, (13) fundamental interaction between electrical, magnetic and mechanical properties.

WE BELIEVE that appropriate and high caliber research in these and other areas will provide the basic background of information and the theories so vital to the proper pursuit of more applied research programs which the government supports in industrial organizations, in various foundations and institutions and in government laboratories. This program therefore will be of benefit to people like you here. The research in these proposed interdisciplinary laboratories will be conducted largely by students who are candidates for advanced degrees under the general supervision of university faculty, but it will also be conducted in part by post-doctorate fellows, professional non-teaching employees, and various non-professional supporting personnel. ARPA has committed an initial amount of $17 million for this basic research in materials. It is hoped that we will not only obtain good results of our basic research but that we also use this program as a means for training highly qualified research specialists who will help us in gaining new fundamental materials knowledge.

You can see from some of the things that I have talked about and from some of the lectures that you have heard from previous speakers at this meeting that your government has a vital interest in many problems involving chemistry, chemical engineering and related subjects. Our interest is to make progress in these specific fields more rapid and more easily applied to government interests and weapons systems in the Department of Defense.

Let me make a few concluding remarks. I have already mentioned the interdisciplinary laboratories in connection with ARPA's materials program. I personally believe that a good deal of our progress in this field and in all other fields will be made by mixing disciplines. For example, the discoveries in solid propellant rocket nozzle materials will come probably as a combination of talents drawn from specialists in chemistry, thermodynamics, metallurgy, combustion or perhaps even plasma physics. New semiconductor materials involve the fields of electrical engineering, basic physics, chemical engineering and statistics. It is my belief that emphasis should be given to have mixed groups of people from different fundamental sciences and from different engineering fields form teams to solve difficult problems. This approach in the past, and I believe in the future, will be more productive because of the wonderful cross-fertilization of ideas from different backgrounds. I personally want to encourage this approach.

As you know, the government is now supporting a large share of the research that is being done by our universities and by our non-profit research laboratories. This is one of the places where a lot of good, fundamental work is being done that will lead to new knowledge. I am very glad to see that every year there are closer relations between our universities and the basic research organizations on the one side and industry and the military on the other. Our chemical industry has seen fit to award scholarships to many universities and to give generously to various college laboratories and college funds and thus to help make the lot of universities somewhat easier. There is one other way of helping our universities that is not fully exploited at this particular time and this concerns our capable chemical research people. They are often lured away from universities and colleges into well paying jobs in industry. This not only diminishes our capability of doing advanced research in these universities but it hurts us pretty badly in making our educational effort less effective in that we are forced to use second-rate people as teachers. In order to counteract this tendency I would like to see industry loan their competent technical people to the universities for a period of time, either on a continuous basis for say a year or on a part time basis. Some of this interchange of personnel is going on, particularly in evening schools, but I don't believe this is enough particularly for getting some high grade, graduate students. Many universities will make temporary academic staff appointments possible. In this manner the universities will not only be provided with capable technical people but they will also have the latest inputs from our complex industrial technology and the latest stimuli to guide their research into the most useful channels. This sabbatical leave in reverse should be encouraged.

I WOULD like to leave you with one last thought. I would like to challenge the individual chemist or the individual chemical engineer in the average non-government organization to devote more of their individual and collective interest and energies to common national and international problems. It is essential I believe that each man devote a portion of his life to local, state or federal government problems. He can do this by serving on a town committee, on a professional technical organization, or on technical committees for the government. It may be a local town committee concerned with sewage problems, or it may be serving on a government advisory committee or on a school board or it may be temporary duty with one of the military services. There are many other good contributions you can make to your government. Many a man with whom I have talked has told me that he is quite satisfied to let the fellows in Washington solve the problems of government for him. The fellows in government cannot really do this without some help from men qualified to give help. Even if it is only an occasional letter to your congressman, your government departments or to your state senator, it will help.

In today's era the importance of science and technology is at its peak. We have for the first time appointed a full time science advisor to our President with a full time staff and throughout all our military operations and our industry we find more and more key technical and scientific positions. Therefore you people who know your chemical problems and your funda-

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# THE HANDLING AND DECONTAMINATION OF RADIOACTIVE MATERIALS

By

THOMAS E. CAREW, Lt. Col., CmlC, USA

*Chief, Radiological Laboratory, Army Chemical Center*

SCIENCE, INDUSTRY, governmental agencies and the military are daily increasing their use of radioactive materials. This is to be expected due to the increased availability of materials from reactors and the constant development of new applications of radioactivity to our expanding technology.

Radioactive substances are now used in many industrial applications for process control. In research, to cite just one example, the use of tracer techniques permits the organic chemist to study the mechanism of complex chemical reactions which would otherwise be impossible to observe. In medicine increasing use is being made of radioactive materials for diagnosis and treatment. In the chemical industry trace quantities of radioactive substances are being used where control of separation, purification, or mixing processes is critical. This widespread use of radioactive substances creates special problems in handling and control, but perhaps of greater importance are the problems concerned with public relations and the necessity for achieving public understanding and acceptance. It is our purpose this morning to briefly outline some of these problems.

First let us consider the need for public understanding and public acceptance of the use of radioactive materials. In the recent past there have been several instances where relatively minor amounts of radioactive contamination have been carried out of industrial laboratories on the shoes and clothing of laboratory technicians. This contamination was subsequently deposited in trace amounts in the houses and communities where the employees lived. One such case occurred in Houston, Texas in June 1956. Due to some unfortunate publicity this case became the subject of sensational nationwide headlines. The news articles referred to the employees and their families as "radioactive." The families found themselves ostracized from their community. Their former friends were even afraid to approach them or speak to them. They were victims of fear and hysteria.

The public relations problems of the industry involved are apparent. Just as apparent is the need for public education and public acceptance of the proper and necessary use of radioactive substances in science and industry.

Although the field of radiation physics is now some sixty years old, it first gained public attention only fourteen years ago with the advent of the atomic bomb. At that time many sensational articles were written with varying degrees of accuracy. Some of them resulted in the creation of confusion and fear. The picture emerged of radioactivity as a new and complex phenomenon highly dangerous and mysterious.

The military and industry alike have a requirement for and a duty to provide the public with an understanding of the nature of radioactivity and the degree of the dangers involved. First it should be stressed that radioactivity is a natural process which is, and always has been, a part of our environment. As we know, there are traces of radioactivity in everything around us. Even our own bodies are made up of some small quantities of radioactive substances. There are, in fact, more than two hundred billion-billion radioactive atoms in the body of an average sized man. This large number of atoms, of course, together make up only a small fraction of one gram of radioactive material. Even the air we breathe is slightly radioactive, and it always has been. Although there is still much to be learned, the phenomenon of radioactivity is far better understood than many other natural processes. It is not mysterious.

As a radioactive substance decays it emits radiations capable of causing ionization in the surrounding medium. Because of this it is possible to devise electronic and other instruments which can detect an event attributable to the decay of a single atom. This is the really unique property of radioactivity, our ability to detect unimaginably small quantities. The mere fact that radioactivity is present does not necessarily indicate that a hazardous condition exists.

Turning our attention to more significant quantities of radiation such as those found in industrial processes and research, public education is needed to change certain common and widespread misconceptions. One of these common misconceptions, apparent from the incident in Houston, Texas is that radiation begets radiation. It is thought that a person or an object subjected to radiation becomes radioactive. This, as you know, is just not true. Radiation resulting from the decay of radioactive substances does not induce radioactivity in the absorbing medium. A better understanding of the radioactive processes would result in more accurate reporting and lessen the chance of panic and hysteria in the future.

Let us consider now the special precautions needed for handling radioactive materials. The exposure of a person to radiation from a source external to his body can be controlled in a number of ways. Maximum per-

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Colonel Carew, who heads the Radiogolical Laboratory at the Army Chemical Center, Maryland, was born in San Francisco on 21 March 1919. He was commissioned as a Reserve officer of Infantry in 1941; served in command and staff assignments in World War II, and as company commander and assistant G-3 of the 7th Division in Korea. His awards include the Purple Heart with Oak Leaf Cluster, Combat Infantry Badge with Star, and Bronze Star Medal.

Since 1952 Colonel Carew has served in various assignments in connection with atomic energy.

He is a graduate of the Infantry School, Command and General Staff College, and the Industrial College of the Armed Forces. He attended the University of California and San Francisco City College, and, later the Naval Postgraduate School from which he received a M.S. degree in Physics. He was integrated in the Regular Army in June, 1959.

mitted exposure levels have been established based on values which should result in no detectable body damage even if continued over the working lifetime of the individual. It is possible to both calculate the amount of exposure to be expected before starting an operation and to measure the actual exposure during an operation. Low level sources of radiation may be handled directly. Higher level sources require remote handling equipment and shielding. Handling procedures have been worked out in detail and are conducted routinely by trained operators.

Of greater concern than exposure to an external source of radiation is the possibility of ingesting small quantities of radioactive substances which may be retained by the body for significant periods of time. These ingested substances can cause localized damage in the body which may, over a period of years, result in leukemia or cancer. It is because of the problem of ingestion that persons while working with radioactive substances, wear gloves and exercise care in personal hygiene. Special shoes or shoe coverings and laboratory clothing are worn so that the street clothing of the workers will not become contaminated with dust particles.

Non-technical operators can be readily taught the special techniques required for the handling of radioactive substances. The procedures involved are not overly restrictive or costly.

Even with careful handling, small quantities of radioactive substances will adhere to the walls of containers, to handling tools, and work surfaces creating a problem of contamination. In addition, accidental spills or improper storage conditions in a structure can result in hazardous amounts of contamination in the air or on the walls, ceiling, floors, or other surfaces.

The unique problem with radioactive contamination, of course, is that there is no way to neutralize the radioactivity. The contamination may be removed from the surface, or sealed in and covered; but there is no way to stop it from decaying.

In general, short half life materials are more dangerous to handle than equal amounts of longer half life materials. This is due to the higher specific activitv of the short half life substances; that is, they are radioactively "hotter." From the decontamination standpoint, however, they are far less of a problem. If the decay products are stable, as they often are, and the half life of the substance is of the order of a few weeks or less, decontamination can be affected by closing off the contaminated area for the period of time necessary for the contaminant to decay naturally to a safe level.

Longer half life materials will generally have to be removed from the contaminated surface by some type of cleaning process. Indeed, ordinary cleaning and washing is the crux of the decontamination problem for radioactive substances. There is no universal radiological decontaminating agent. Radioactive substances have chemical and physical properties which are in all respects identical to those of the stable forms of the same elements. Radioactive substances in use, cover the entire range of the periodic table. It therefore follows that a universal decontaminating agent based on chemical reactions can not be found. Solvents which are effective for the specific substances comprising an actual contamination may of course be used to decontaminate. Perhaps the most common method of decontamination consists of the use of detergents and scrubbing to clean the contaminated surface. This method certainly has the most universal application; however, all standard methods of cleaning may be used. These methods include: sweeping with brooms, mopping, scrubbing, flushing with water, using high pressure water sources, steam cleaning, vacuum cleaning, buffing, grinding, sand blasting; using detergents, complexing agents, organic solvents, caustics, inorganic acids, or any combination of these.

An effective way to deal with the decontamination problem in a laboratory or industrial plant, is to plan for it in advance. The walls and ceilings may be painted with strippable paints and the floor may be covered with removable tiles. Subsequent contamination of the room is then less of a problem. Porous surfaces such as bare wood or concrete in such areas should be avoided as they are especially difficult to decontaminate. Effective decontamination of these generally requires removal of the top layer of the surface.

The major problem of radiological decontamination is the ultimate disposal of the contaminant. Once it is removed from the contaminated surface it must be collected and disposed of in a manner which will not result in future contamination problems. This means, for example, if large quantities of water are used for the clean-up operation, the run-off must be collected in tanks or ditches. Concentration of the contamination may then be effected by settling, precipitation, or evaporation of the water. The concentrated contaminant may then be placed in concrete filled drums for disposal at sea. The disposal problem is a large one. The Chemical Corps has been given this responsibility for the Department of the Army.

We have looked briefly at some of the problems involved in the handling of radioactive materials. Decontamination of an extensive area can be a time-consuming and costly operation. Much of this time and cost, however, may be saved by proper preparation of the working areas before the contamination occurs. It appears that one of the most pressing problems is the establishment and maintenance of good public relations and public support. With this, we can expect to make full use of the advantages offered by radioactivity with ever expanding applications to science and industry.

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## BANQUET SPEECH

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mentals can make a contribution. Without inputs from the grass roots, we in government shall be unable to determine what kind of chemical devices we should have in our weapons systems, what kind of regulations we should impose on the chemical industry, what kind of regimentation we should propose for organized research, what type of chemistry we should teach to our young men, what kind of common interests there are between various branches of government involved in chemical sciences, how to control smog or what kind of use should be made of foreign chemical information. In addition there are many important local, state and federal issues. These are but a few of the critical questions to which most of you can make a contribution by voicing your opinion to the right people at the right time and this I urge you to do for your own sake as well as the sake of your country.

# WITH THE CHEMICAL CORPS

## GENERAL WALMSLEY RETIRES

EDGEWOOD, MD.—Brigadier General Harold Walmsley, commander of Army Chemical Center here, and the Chemical Corps Materiel Command, which also has had its headquarters at this location for the past two years, retired from active military service on September 30. He has been succeeded in both these positions by Colonel Roy W. Muth.

A graduate of West Point and veteran of more than 27 years' commissioned service, General Walmsley was honored at a retirement parade here on September 28. Following the parade there was a reception and buffet in honor of General and Mrs. Walmsley at the Officers' Open Mess. The Walmsleys will reside in Phoenix, Arizona.

General Walmsley is a native of Darwen, Lancashire, England. He came to this country as a youth and graduated from a Stamford, Connecticut, high school. In the summer of 1927, he joined the National Guard and a year later entered the U.S. Military Academy. At graduation in 1932 he was commissioned into the Infantry.

After a number of infantry assignments, General Walmsley transferred into the Chemical Corps (then the Chemical Warfare Service) in 1938.

In the summer of 1940, he was assigned to the Panama Canal Zone, where he held various positions including that of chemical officer of the Panama Canal Department. Returning in 1943 he attended the Chemical Corps School advanced course and subsequently the Command and General Staff College.

In the later years of the war, he served as chemical officer first of the U.S. Fourth Army, and then of the U.S. Ninth Army in the European Theater of Operations. It was during the latter assignment of Walmsley, then a Colonel, that the Ninth Army, in cooperation with British and Canadian forces, carried out the famous 60-mile smoke screen along the Rhine river. While not continuous as to time and place, the deceptive screening, which went on for two weeks, preliminary to subsequent actual river crossing operations, has been referred to as probably having covered more area than any other screen in all military history. American chemical troops involved in the operation included both smoke generator and chemical mortar units with the Ninth Army.

Among his postwar assignments were those of chief of the training branch, Office of the Chief Chemical Officer; student at the Industrial College of the Armed Forces; deputy commander, Chemical Corps Materiel Command (then located in Baltimore), from 1951 to 1954; and commander of the New York Procurement District in New York City. In 1957 he became commander here and in December 1957 was promoted to brigadier general.

General and Mrs. Walmsley have two sons, Alan, 20; and Mark, 7.

## COL. MUTH HEADS CHEMICAL CORPS MATERIEL COMMAND

EDGEWOOD, MD. — Colonel Roy W. Muth, commanding officer of the Chemical Corps Engineering Command for more than a year, has succeeded Brig. General Harold Walmsley as commander of Army Chemical Center and the Chemical Corps Materiel Command. General Walmsley retired September 30, 1959.

The Materiel Command, with headquarters here, supplies chemical warfare equipment to the U.S. Armed Forces all over the world. Under an integrated command set-up, Colonel Muth will also serve as Army Chemical Center's post commander.

A 1930 West Point graduate, Colonel Muth served as chemical officer at Continental Army Command headquarters at Fort Monroe, Va., before coming here in the summer of 1958. A native of New York City, he has a Masters degree in Business Administration from Harvard. His Service schooling includes the Infantry School, the Chemical Corps School, the Command and General Staff College, and the Armed Forces Staff College.

During World War II, he served in France and Germany commanding a chemical mortar battalion, and later was chemical officer first of the VIII Corps then of the Ninth Army.

## NEW DEPUTY COMMANDER AT ARMY CHEMICAL CENTER

EDGEWOOD, MD.—Col. Gilbert P. Gibbons has been assigned as deputy commander of Army Chemical Center and the Chemical Corps Materiel Command.

He succeeds Col. C. B. Drennon, Jr., recently assigned as a student at the Industrial College of the Armed Forces.

A native of Ohio, Colonel Gibbons has a B.S. degree in chemical engineering from Case Institute of Technology. Before entering the Army in 1941, he was employed as technical director of a Philadelphia paint and varnish concern. During World War II, he served in both Hawaii and the Philippines; received the Bronze Star and a number of other decorations. He has attended the Industrial College of the Armed Forces and the advanced management program at Harvard.

## COL. McNARY HEADS ENGINEERING COMMAND

EDGEWOOD, Md.—Colonel Charles H. McNary has been named to head the Chemical Corps Engineering Command, with headquarters at Army Chemical Center here.

He succeeds Colonel Roy W. Muth, who took command of the Chemical Corps Materiel Command at the beginning of October.

Prior to his assignment here a year ago, Colonel McNary, a veteran of over 17 years' active military service, commanded the 81st Chemical Group at Fort Bragg, N.C. For the past several months he has served as director of weapons systems engineering in the Engineering Command.

He is a graduate of Rennselaer Polytechnic Institute in Troy, New York.

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## COL. LAVERNE PARKS NAMED FT. DETRICK COMMANDER

Colonel Donald G. Grothaus, Commanding Officer, Fort Detrick, Frederick, Maryland, has been assigned to the staff of the Deputy Chief of Staff for Logistics, Department of the Army, effective November 4.

Colonel Laverne Parks, Assistant Commandant, The Chemical Corps School, Fort McClellan, Alabama, will replace Colonel Grothaus at Fort Detrick.

## T A P S

**Colonel Joseph D. Sears, A.U.S., who served the Chemical Corps with distinction in two wars, died of a cerebral hemorrhage at Guadalajara, Mexico at the age of 81 years. He is buried at Chapala Jalisco, Mexico, where he has lived since retirement.**

**In WWI he served as the CO of Camp AA Kendrick, Lakehurst, N.J., the first chemical warfare training center in the U.S. Between wars he was very active in reserve affairs in the N.Y.-N.J. area. Early in WWII he returned to active duty to head civil defense training in chemical warfare protection. When these schools were disconinued in 1943, Col. Sears became Commanding Officer of Camp (now Fort) Detrick, Maryland, the B.W. Research Center. (H.A.K.)**

## COL. STOESSEL S. BARKSDALE

EDGEWOOD, MD.—Colonel Stoessel S. Barksdale, 54, who had been assigned to Army Chemical Center here as commander of Eastern Chemical Depot since July 1958, died at Aberdeen Proving Ground Hospital on September 21, 1959 following a short illness.

A native of Fern Bank, Alabama, Colonel Barksdale was a graduate of the University of Alabama. He taught history and chemistry in Alabama public schools until called to active duty in 1942. He was integrated into the Regular Army in 1947.

After serving in Europe in World War II, Colonel Barksdale was assigned to the Far East Command. Later he served as assistant commandant of the Chemical Corps School at Fort McClellan, Alabama, and, after that duty, he served on the staff and faculty of the Army War College, Carlisle Barracks, Pa.

Among his decorations Colonel Barksdale held the Bronze Star, the Purple Heart and the Commendation Ribbon. He is survived by his wife, the former Ruth Hunt Sloane, and a brother, Jelkes Barksdale, of Auburn, Alabama.

## ENLISTED SCIENTIST HONORED FOR PAPER IN RESA CONTEST

EDGEWOOD, MD. — Private First Class Harvey Yurow, a 27-year old New Yorker, has been named recipient of an annual technical paper award established this year by the Army Chemical Center branch of the Scientific Research Society of America (RESA).

He received a $25 award and a certificate of achievement at a dinner in his honor May 7 at Gunpowder Mess.

Yurow's paper on "Detection of Monobasic Phosphoric and Phosphonic Acid Esters by Chemical Activation," was selected as the best of the papers submitted by enlisted scientists assigned to Army Chemical Center.

The technique developed by Yurow and described in his winning entry is capable of detecting as little as one one-hundredth of a microgram of the material involved, and is valuable in studies of organo-phosphorous insecticides and chemical agents containing phosphorous.

# CHEMICAL CORPS MUSEUM OF INTEREST TO BOTH LAY VISITORS AND DESIGNERS OF MUNITIONS

EDGEWOOD, MD.,—The Chemical Corps Museum, a venerable institution almost as old as the Chemical Corps itself, is taking on new importance and significance.

Long a showplace of the Corps, the Museum features a fascinating array of chemical warfare equipment; more than 8000 items gathered from all over the world.

Like most museums, the Chemical Corps display has been prized mostly for its historical significance. But in recent years, the Chemical Corps has come to recognize a function of the Museum even more valuable than its historical and public relations aspects.

Quietly and without fanfare, the Museum has, over the years, become an indispensable reference source for researchers, development men and engineers.

"It's like having a talkative uncle who's been around," explains one Army engineer.

Charged with the responsibility for keeping the Chemical Corps up-to-date in an era of fast-moving technology, these men are unanimous in their praise of the Museum.

"It's mighty valuable for use in our day-to-day work," says Walter Bradley, chief of the flame section of the Chemical Warfare Laboratories' Munitions Development Division. "With access to so many old models and foreign material, we are able to see first hand many of the ideas that have been tried in the past and apply them to our present-day work."

As an example, Dr. Bradley cited the Korean War fougasse, the napalm-filled mine used against the Chinese Communists' mass assaults. "The idea for that," he says, "came from the First World War, and we saw it in the Museum."

Museum curator William E. Nichols explains that by viewing old equipment, engineers avoid mistakes made by others in the past, and often incorporate desirable features of obsolete equipment into new designs.

**RUSSIAN MORTAR—William E. Nichols, Museum curator, explains the workings of a Soviet mortar, captured in Korea. Such a weapon could be used to fire rounds filled with a chemical warfare agent. Museum visitors are Miss Jennie Wilson (center) of Baltimore; and Miss Mary Wimmer of Joppa, Maryland. Both are employed by the Chemical Corps Engineering Command.**

"Many times," Mr. Nichols adds, "people in the labs need components of old equipment in constructing or testing new items. If we couldn't provide them from the Museum, the components would have to be fabricated at a good deal of expense and delay to vital programs."

Frank Shanty, an engineer in the laboratories' Protective Development Division, cites another vital function of the Museum: "When I first joined the Chemical Corps as a civilian employe in 1950, I spent a couple of weeks studying chemical warfare equipment in detail.

"It's an ideal way for a newcomer to familiarize himself with the Chemical Corps and just what's been done in the past in his particular specialty," he continues.

Allen E. West, chief of the respirator branch of the Protective Development Division, points out that a Museum tour is often a quicker and more effective way of researching an old piece of equipment than going through the literature on the subject.

"In a couple of hours, a man can do in the Museum what it would take him weeks to do in going through the literature," he explains.

To accommodate the ever-increasing stream of serious visitors, Museum director Major Samuel Cox and Curator Nichols are planning a major reorganization of the huge display, which will divide it into two areas; one for casual visitors to the post, the other a technical reference museum for researchers and engineers.

The result, they say, will be the elimination of the duplication now existing in the public areas, and a con-

**"A PAIR OF ARTIFICIAL LUNGS"—Lt. John W. Kelley models the device invented by a Harford County (Md) clergyman in 1915 "to meet the menace" of gas warfare, initiated only a few days earlier by the Germans at Ypres, Belgium. The Chemical Corps Museum at Army Chemical Center traces the development of the gas mask of World War I to today's modern, multi-purpose, protective mask.**

centration of technical items of interest to men planning the future of the Chemical Corps.

The Museum was established in 1919 at the close of the First World War. Its exhibits tell the story of chemical warfare from its most rudimentary beginnings to the present.

The bulk of the foreign material in the Museum was captured during World War II from a German museum at the German Army Gas School, located at Celle, a small town near Hanover.

A sampling of what a visitor to the Museum will see:

—An oversized flyswatter-like fan, made of wood and canvas, used by American troops in World War I to fan toxic gas fumes out of the trenches.

—Early smoke generators called "salamanders," similar to the smudge pots used in Florida citrus groves, which were used to obstruct possible hostile observation of Edgewood Arsenal from the air early in World War II.

—Incendiary bombs which the Japanese attached to giant balloons and floated across the Pacific in the last desperate days of World War II. The bombs were found as far east as Detroit.

—Gas mask designed for camels, apparently for use by Rommel's Afrika Korps in World War II.

—A German mask with a single large circular eyepiece equipped with a "windshield wiper" to clean off moisture.

One of the exhibits is especially interesting not only in itself (artificial lungs) but because of its inventor, an Episcopal clergyman.

"On April 25, 1915, when news of the Germans having used poison gas reached Baltimore, I set myself immediately to work on inventing some way to meet the menace," wrote The Reverend William A. Crawford-Frost, pastor of the Protestant Episcopal Church at Emmorton, Maryland, and an amateur inventor. Soon afterwards he developed a "pair of artificial lungs and trachea made of leather cloth and stuffed with excelsior, tow, (and) cheesecloth . . . to be saturated with a neutralizing solution."

The United States Government rejected the idea at the time on the grounds that "it reverses the natural order of breathing to inhale through the mouth."

In the years that followed, Mr. Crawford-Frost fought a long struggle to win recognition for his invention, claiming it to be the basis for the gas masks subsequently developed by many nations.

He was unsuccessful and official recognition never came.

Curator Nichols recommends the display for civilian as well as military personnel, children as well as adults. He provides a guided tour for most of the 500-odd visitors who show up at the Museum each month.

"You don't have to be in the Chemical Corps to enjoy the Museum," Mr. Nichols emphasizes. "Kids love it, especially the guns—anything they can aim. Adults are usually interested in the newer civilian protective equipment, as well as the historical aspect of the display."

Groups interested in visiting the display at night or on the weekends are invited to contact the Post Public Information Officer to make arrangements. Individuals or family groups may visit the Museum any weekday from 8 a.m. to 4:30 p.m. Special visitor permits are issued by military police at the Army Chemical Center gate.

# MISCELLANEOUS

## HIGH ENERGY LIQUID PROPELLANTS

*(Continued from page 50)*

Slide #6

**Additives**

A. Freezing Point Depressants
B. Corrosion Inhibition
C. Hypogolic Ignition
D. Improved Thermal Stability
E. Coloring
F. Getters
G. Partial Catalysts

## AMERICAN LEGION TO SET UP CIVIL DEFENSE RESCUE SQUADS

The American Legion has announced a new national civil defense program to develop hundreds of light duty rescue squads ready in disaster or war to assist State and local governments.

The Legion program has the endorsement of the Office of Civil and Defense Mobilization, and OCDM Director, Governor Leo A. Hoegh, has called on the 2,500 State and local civil defense directors throughout the United States to cooperate with the Legion. The program has been approved by the American National Red Cross, the National Association of State and Territorial Civil Defense Directors, and the U. S. Civil Defense Council.

With its rescue squads organized and ready for action, the Legion will be in a position to give support to the nation's non-military defense. The Legion program supports OCDM's view that the ability of the United States to survive an enemy attack will depend on how well local governments fulfill their responsibilities to the people.

A National Advisory Committee has been formed to expedite the program. It includes Director Hoegh; General Alfred Gruenther, President of the Red Cross; General Ralph J. Olson, President of the National Association of State and Territorial Civil Defense Directors; Walter P. Halstead, President of the U. S. Civil Defense Council; Preston J. Moore, National Commander of the American Legion; and Mrs. Charles W. Gunn, National President of the Legion Auxiliary.

Each rescue squad is to be made up of a squad leader, a deputy squad leader and six teams of four persons each. Rescue squads use a variety of tools. Their vehicles range from amphibious trailers to four-wheel drive trucks capable of carrying a rescue team and its equipment over the roughest terrain and into remote areas.

The Federal government will assist local communities in the purchase of vehicles and equipment. Under OCDM's Contributions Program, up to 50 per cent of the cost is available in the matching funds.

## SOUVENIR DESK FLAG OF THE CHEMICAL CORPS AVAILABLE

A popular souvenir featured by the U.S. Army Chemical Corps School Book Department at Fort McClellan, Alabama, is a miniature Chemical Corps flag suitable for use as a desk set or framing. The flag scaled to size is 4" by 6", is made of silk with gold fringe and sells for less than two dollars. The flag is particularly attractive when displayed with miniature U.S. and U.S. Army Flags, which are also available.

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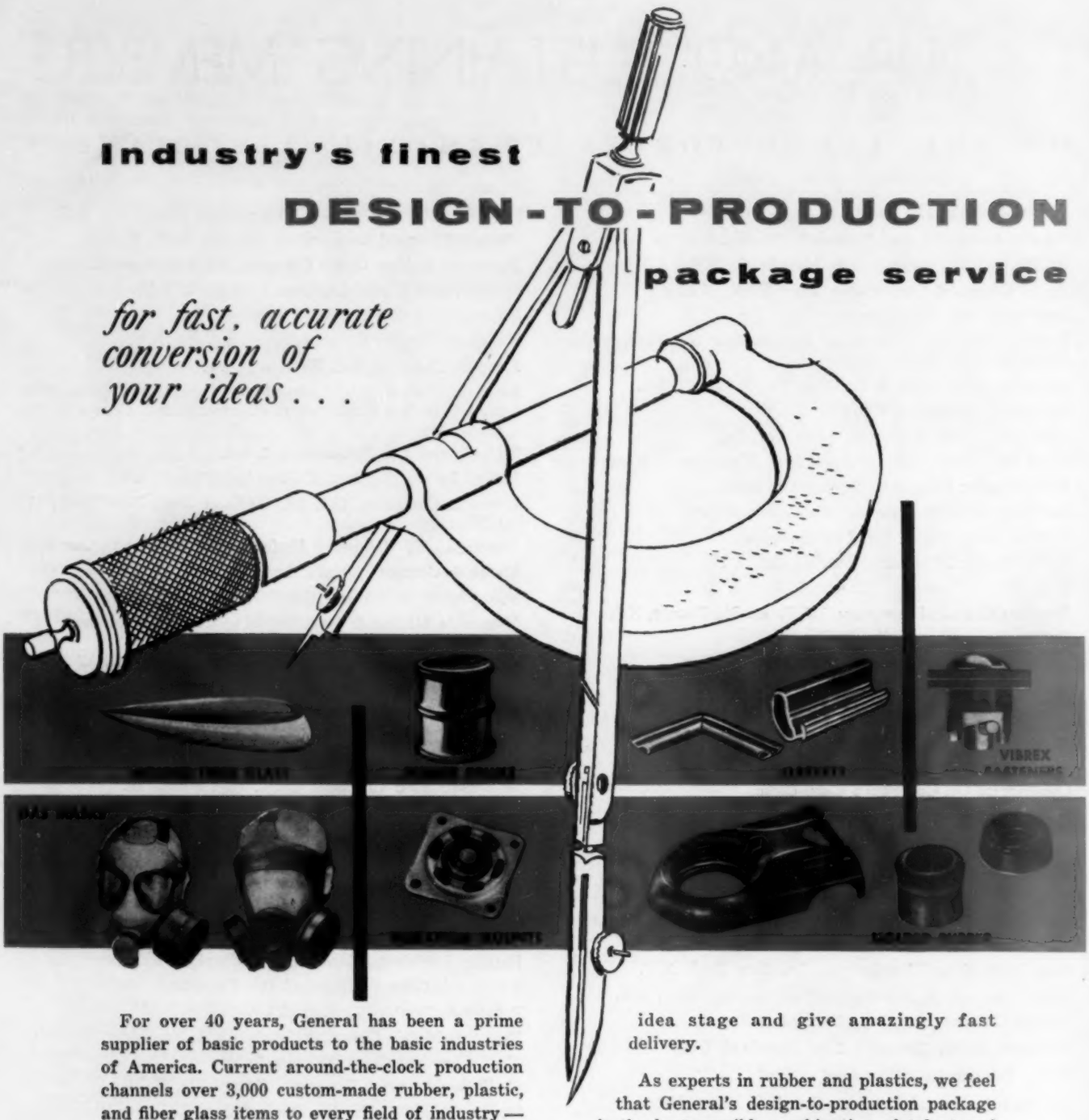


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